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WIRE
IN
ELECTRICAL CONSTRUCTION

JOHN A. ROEBLING'S SONS
COMPANY
TRENTON, NEW JERSEY

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WIRE

IN

Electrical Construction

JOHN A. ROEBLING'S SONS COMPANY

Main Office: TRENTON, N. J.

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MAL

PREFATORY.

The object of this book is to give in a convenient form the properties and dimensions of bare and insulated wires and cables used in electrical construction. No attempt has been made to describe the uses of wire in any of the applications of electricity. To go into this would require that the whole field of electrical engineering be covered.

It is believed that some of the matter is new. All of the tables have been very carefully computed, and are believed to be correct.

In nearly all cases the formulas and constants used in computing tables are given, so that the user can determine at once the basis from which the table was calculated. A considerable amount of work has been done in testing samples to determine the proper constants. In many cases this has taken more time than the actual preparation of the tables.

It is hoped that the work will be acceptable to the users of electrical wires, and that some of the labor involved in the preparation of these tables will be saved to those using the book.

JOHN A. ROEBLING'S SONS CO.

TRENTON, N. J., February, 1906.

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PREFACE.

This book of tables was first published in 1892, under the title of "TABLES FOR ELECTRICAL ENGINEERS." In 1897 the book was revised and given its present title, "WIRE IN ELECTRICAL CONSTRUCTION." In 1916 the book was revised and published under the same title. The preface of the second edition tells the object of the book, which is true of the third edition.

Above all other things this is a collection of tables of the properties of copper wire. The resistance of a mil foot of copper at 20° C, or 68° Fahr. used in the three editions is as follows:

1892 edition 10.3517 ohms.
1897 edition 10.3541 ohms.
1916 edition 10.3712 ohms.

The weights of copper wire were figured from the same formula $d^2 \times .003027 =$ pounds per 1000 feet in both the 1897 and the 1916 editions. The resistance of copper wire in the tables in all editions is figured at 100% conductivity.

October, 1916.

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Printed by Roebling Press.

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WEIGHTS AND MEASURES.

The fundamental units in United States measures are the meter and the kilogram.

1 meter = 39.37 inches.
1 kilogram = 15 432.356 39 grains.

These values define the inch and the grain, and are definite, made so by an executive order. All the values of the weights and measures in common use are derived from these values. The following are also fixed by law:

A liquid gallon = 231 cubic inches.
A bushel = 2 150.42 cubic inches.

In Great Britian there are two systems of weights and measures, the Imperial and the Metric. The relation between the two is fixed by law.

1 meter = 39.370 113 inches.
1 kilogram = 15 432.356 39 grains.
1 gallon = 277.41 cubic inches.
1 bushel = 2 219.28 cubic inches.

The English units of length are less than those in the United States by about three parts in one million. The English grain, and consequently the English measures of weights, are the same as ours. The English gallon is about one-fifth larger than ours, and the English bushel is about 3%. The following table shows the relative values of the units in Great Britian and the United States:

UNITS.	GREAT BRITIAN.	UNITED STATES.
Meter, inches	39.370 113	39.37
Kilogram, grains	15 432.356 39	15 432.356 39
Gallon, cubic inches	277.41	231.
Bushel, cubic inches	2 219.28	2 150.42

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A measure of capacity may be defined by giving its contents in cubical units or by specifying the weight of water which it will hold. The British gallon is defined as a measure holding ten pounds of water at 62° F, and a bushel as holding eighty pounds of water at 62° F. Translating this into cubic inches is not so easy as would appear, and the values of an English gallon and an English bushel in cubic inches are consequently indefinite. The American units of capacity are given in cubic inches, and the amount of water that they will hold is not defined.

Linear Measure.

12 inches (in.)	= 1 foot (ft.)
3 feet	= 1 yard (yd.)
5½ yards or 16½ feet	= 1 rod (rd.)
40 rods	= 1 furlong (fur.)
8 furlongs or 5 280 feet	= 1 mile (mi.)

Surveyors' Linear Measure.

7.92 inches	= 1 link (l.)
25 links	= 1 rod (rd.)
4 rods or 66 feet	= 1 chain (ch.)
80 chains	= 1 mile (mi.)

The unit most used is a chain, and lengths are expressed in chains and hundredths of a chain. Each link is a hundredth of a chain.

Square Measure.

144 square inches	= 1 square foot (sq. ft.)
9 square feet	= 1 square yard (sq. yd.)
30¼ square yards	= 1 square rod (sq. rd.)
160 square rods	= 1 acre (A.)
640 acres	= 1 square mile (sq. mi.)

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Surveyors' Square Measure.

625 square links	= 1 square rod (sq. rd.)
16 square rods	= 1 square chain (sq. ch.)
10 square chains	= 1 acre (A.)

Cubic Measure.

1728 cubic inches	= 1 cubic foot (cu. ft.)
27 cubic feet	= 1 cubic yard (cu. yd.)
16 cubic feet	= 1 cord foot (cu. ft.)
8 cord feet 128 cubic feet	= 1 cord of wood (cd.)
24¾ cubic feet	= 1 perch of stone or masonry (pch.)

Liquid Measure.

4 gills (gi.)	= 1 pint (pt.)
2 pints	= 1 quart (qt.)
4 quarts	= 1 gallon (gal.)
31½ gallons	= 1 barrel (bbl.)
2 barrels or 63 gallons	= 1 hogshead (hhd.)

One gallon equals 231 cubic inches.

Dry Measure.

2 pints	= 1 quart (qt.)
8 quarts	= 1 peck (pk.)
4 pecks	= 1 bushel (bu.)

One bushel equals 2150.42 cubic inches.

Capacity in Cubic Inches.

	Liquid.	Dry.	Apothecaries' Liquid.
Pint	28.875	33.600 312 5	28.875
Quart	57.75	67.200 625	.....
Gallon	231.	.....	231.
Peck	.....	537.605	.....

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Avoirdupois Weight.

16 drams	= 1 ounce (oz.)
16 ounces	= 1 pound (lb.)
100 pounds	= 1 hundredweight (cwt.)
20 hundredweight or 2000 pounds	= 1 ton (T.)

7000 grains equal one pound.

Long Ton Table.

16 ounces (oz.)	= 1 pound (lb.)
28 pounds	= 1 quarter (qr.)
4 quarters	= 1 hundredweight (cwt.)
20 hundredweight or 2240 pounds	= 1 ton (T.)

Troy Weight.

24 grains (gr.)	= 1 pennyweight (pwt.)
20 pennyweights	= 1 ounce (oz.)
12 ounces	= 1 pound (lb.)

5760 grains equal one pound.

Apothecaries' Weight.

20 grains (gr.)	= 1 scruple (sc.) ℈
3 scruples	= 1 dram (dr.) ʒ
8 drams	= 1 ounce. ℥
12 ounces	= 1 pound (lb. or ℔.)

5760 grains equal one pound.

Weight in Grains.

WEIGHTS.	TROY.	APOTHECARIES.	AVOIRDUPOIS.
Scruple	.....	20	.....
Pennyweight	24	.....	.....
Dram	.....	60	27.343 75
Ounce	480	480	437.5
Pound	5760	5760	7000.

Dram, drachm, and drachma mean the same.

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Apothecaries' Fluid Measure.

60 minims or drops	= 1 fluid dram. f ʒ
8 fluid drams	= 1 fluid ounce. f ℥
16 fluid ounces	= 1 pint (O.)
8 pints	= 1 gallon (cong.)

Counting.

12 units	= 1 dozen.
12 dozen	= 1 gross.
12 gross	= 1 great gross.
20 units	= 1 score.

Paper.

24 sheets	= 1 quire.
20 quires	= 1 ream.
2 reams	= 1 bundle.
5 bundles	= 1 bale.

A ream of 500 sheets is commonly used at the present time.

Measures of Angles.

60 seconds (″)	= 1 minute (′.)
60 minutes	= 1 degree (°.)
30 degrees	= 1 sine (S.)
12 sines or 360 degrees	= 1 circumference (cir.)

English Money.

4 farthings (far.)	= 1 penny (d.)
12 pence	= 1 shilling (s.)
20 shillings	= 1 pound or sovereign.

One pound equals $4.8665.

The gold coins are the sovereign and the half sovereign. The guinea (21 s.) and the half guinea (10 s. 6 d.) are no longer coined.

The silver coins are the crown (5 s.), the half crown (2 s. 6 d.), the florin (2 s.), the shilling, the sixpenny piece, the fourpenny piece, and the threepenny piece.

The copper coins are the penny, half-penny, and farthing.

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Circular Measure.

The natural unit for the area of a square or rectangular surface is a square whose side is the unit of length. The natural unit for the area of a circle is a circle whose diameter is the unit of length. It is customary in this country to measure the area of wires in circular mils, but abroad the area of wires is measured in square inches. It is customary everywhere to give the breaking stress of a wire in pounds per square inch. It would be more simple and more appropriate to give the breaking stress of a round wire in pounds per circular inch. Where the requirements are expressed in pounds per square inch they may easily be reduced to pounds per circular inch by multiplying by .7854. 60,000 pounds per square inch corresponds to 47,124 pounds per circular inch. The area of a wire in circular units is equal to its diameter squared, and to find the breaking weight of a wire per circular inch we may divide the breaking weight of a wire by the square of the diameter in inches. A wire one hundred mils in diameter, breaking at 500 pounds, has a breaking stress of 50,000 pounds per circular inch.

Metric System.

The fundamental units of length, mass, and time are the international meter, the international kilogram, and the mean solar second. The customary units of the United States, the inch, pound, etc., are derived from the first two by fixed relations. The meter and kilogram are defined in terms of certain standards maintained at the International

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Bureau of Weights and Measures in France; each nation has copies of these so-called prototype standards. It is a matter of interest and some practical convenience that when the length of the meter was originally specified it was taken to be one ten-millionth part of a quadrant of the earth's circumference, and that the kilogram was taken to be the mass of a cubic decimeter of water at its maximum density. These relations hold as closely as the accuracy of measurements permitted at the time they were adopted. The progress of refined measurements has naturally shown extremely slight departures between the fundamental standards and the orginal specifications. While the units are now defined in terms of the standards themselves and have been cut loose from the historical specifications, nevertheless these original relations still apply with an accuracy far exceeding the requirements of practical measurements.

Milli (m)	= 1/1000	Deka (dk)	=	10
Centi (c)	= 1/100	Hecto (h)	=	100
Deci (d)	= 1/10	Kilo (k)	=	1 000

These prefixes are used in connection with the following units:

Weight .....gram (g)
Length.....meter (m)
Area .....square meter (m^2)
Capacity.....cubic meter (m^3)

In addition to these are the following units:

Are (a)	=	100 m^2, measure of land.
Hectare (ha)	=	100 are.
Stere (s)	=	m^3, measure of capacity.
Liter (l)	=	measure of capacity.

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There are eight measures of length based on the meter, but of these only the following are in common use:

Millimeter (mm)	= 1/25 inch,	approximately.
Centimeter (cm)	= 2/5 "	"
Kilometer (km)	= 5/8 mile,	"

The following units of weight are in common use:

Milligram (mg)	= .015 grains,	approximately.
Gram (g)	= 15 "	"
Kilogram (kg)	= 2.2 lbs.,	"

As a measure of capacity the cubic centimeter (cm^3) is frequently used, abbreviated to c. c.

It is to be noted that the ratio between the linear, square, and cubic units is not the same.

10 dm	=	1 m
100 dm^2	=	m^2
1000 dm^3	=	m^3

Our weights and measures are criticised because we express a quantity in two units. We say that a room is 24 ft. 6 in. long.

English money is expressed in pounds, shillings, and pence.

We sell wire by the pound and weigh it in pounds and ounces.

A great many of the conveniences of a decimal system of units may be obtained with our own units. Instead of weighing in pounds and ounces we can just as readily weigh in pounds and hundredths of a pound. Such scales are at the present time on the market.

Instead of expressing a distance in feet and inches, or in miles and feet, we might express it in feet and decimals of a foot, or in miles and

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decimals of a mile. We seem to select a unit in accordance with the magnitude of the quantity to be measured. Long distances are measured in miles or kilometers; shorter distances in yards, feet, or meters; and yet shorter distances in inches, centimeters, or millimeters. Having decided on our unit, the next problem is one of sub-divisions. The inch is divided into halves, fourths, eighths, etc., and for machine work this method seems to have certain advantages all of its own. We might divide the inch into tenths, hundredths, and thousandths just as readily.

Weight of Water.

The table on the next page gives the apparent weight of certain volumes of water, weighed with brass weights in air, humidity 50%, barometer reading 76 centimeters, not reduced. The weighing is supposed to be made at 20° C, the air and the water being at the same temperature. At any temperature between 18° C and 22° C no error will be introduced greater than one milligram per 100 c. c. When weighed in a vacuum with all the usual corrections applied, a liter of water at 4° C weighs one kilogram and equals 1.000 027 cubic decimeters. A cubic decimeter of water weighs under these conditions .999 973 kilograms.

One gram per cubic centimeter equals,

62.428 327 pounds per cubic foot.
.036 127 504 pounds per cubic inch.
252.892 529 grains per cubic inch.

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WEIGHT OF WATER IN AIR.

Weighing at 20° C.

Degrees. C.	Degrees. F.	Grams per cubic cm.	Cubic cm. per gram.	Pounds per cubic foot.	Pounds per cubic inch.	Grains per cubic inch.
0	32.0	.998 81	1.001 19	62.354	.036 084 512	252.592
1	33.8	.998 87	1.001 13	62.358	.036 086 680	252.607
2	35.6	.998 91	1.001 09	62.360	.036 088 125	252.617
3	37.4	.998 94	1.001 06	62.362	.036 089 209	252.624
4	39.2	.998 94	1.001 06	62.362	.036 089 209	252.624
5	41.0	.998 94	1.001 06	62.362	.036 089 209	252.624
6	42.8	.998 91	1.001 09	62.360	.036 088 125	252.617
7	44.6	.998 87	1.001 13	62.358	.036 086 680	252.607
8	46.4	.998 82	1.001 18	62.355	.036 084 874	252.594
9	48.2	.998 75	1.001 25	62.350	.036 082 345	252.576
10	50.0	.998 67	1.001 33	62.345	.036 079 455	252.556
11	51.8	.998 58	1.001 42	62.340	.036 076 203	252.533
12	53.6	.998 47	1.001 53	62.333	.036 072 229	252.506
13	55.4	.998 35	1.001 65	62.325	.036 067 894	252.475
14	57.2	.998 22	1.001 78	62.317	.036 063 197	252.442
15	59.0	.998 07	1.001 93	62.308	.036 057 778	252.404
16	60.8	.997 92	1.002 08	62.298	.036 052 359	252.367
17	62.6	.997 75	1.002 26	62.288	.036 046 217	252.324
18	64.4	.997 57	1.002 44	62.277	.036 039 714	252.278
19	66.2	.897 38	1.002 63	62.265	.036 032 850	252.230
20	68.0	.997 18	1.002 83	62.252	.036 025 625	252.179
21	69.8	.996 97	1.003 04	62.239	.036 018 038	252.126
22	71.6	.996 75	1.003 26	62.225	.036 010 090	252.071
23	73.4	.996 52	1.003 49	62.211	.036 001 780	252.012
24	75.2	.996 28	1.003 73	62.196	.035 993 110	251.952
25	77.0	.996 03	1.003 99	62.180	.035 984 078	251.889
26	78.8	.995 76	1.004 26	62.164	.035 974 324	251.820
27	80.6	.995 49	1.004 53	62.147	.035 964 569	251.752
28	82.4	.995 21	1.004 81	62.129	.035 954 453	251.681
29	84.2	.994 93	1.005 10	62.112	.035 944 338	251.610
30	86.0	.994 63	1.005 40	62.093	.035 933 499	251.534
35	95.0	.993 01	1.007 04	61.992	.035 874 973	251.125
40	104.0	.991 20	1.008 88	61.879	.035 809 582	250.667
45	113.0	.989 2	1.010 92	61.754	.035 737 327	250.161
50	122.0	.987 0	1.013 17	61.617	.035 657 847	249.605
55	131.0	.984 7	1.015 54	61.473	.035 574 753	249.023
60	140.0	.982 2	1.018 12	91.317	.035 484 435	248.391
65	149.0	.979 6	1.020 82	61.155	.035 390 503	247.734
70	158.0	.976 8	1.023 75	60.980	.035 289 346	247.025
75	167.0	.973 9	1.026 80	60.799	.035 184 576	246.292
80	176.0	.970 8	1.030 08	60.605	.035 072 581	245.508
85	185.0	.967 6	1.033 48	60.406	.034 956 973	244.699
90	194.0	.964 3	1.037 02	60.200	.034 837 752	243.864
95	203.0	.960 9	1.040 69	59.987	.034 714 919	243.004
100	212.0	.957 4	1.044 50	59.769	.034 588 472	242.119

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CONVERSION TABLES.

The numbers in the conversion tables may be used as multipliers or divisors. 12,782 yards may be changed to meters by multiplying by .914 401 829 found opposite "yards" and under "meters." The first four figures only would be used in ordinary calculations. The same result will be obtained by dividing by 1.093 611 found opposite "meters" and under "yards."

The factor for changing millimeters to yards is .001 093 6. If more figures are required they may be found opposite the kilometer. Repeating figures are not given to the nearest last unit but are put down as they come.

.11 = 1/9	.55 = 5/9
.22 = 2/9	.66 = 2/3
.33 = 1/3	.77 = 7/9
.44 = 4/9	.88 = 8/9

The stars (*) appearing on the conversion tables indicate the fundamental units used.

In computing the table on Measures of Length, the values in the first vertical column under "inch" were easily obtained. The values in column two, divided by twelve, give the values for the column headed "foot," and by 36, 63360 and 39.37, the values in the other vertical columns headed "yard," "mile," and "meter."

All the values in a horizontal line are equal. If the values in the top horizontal line opposite millimeters were first found, the values in the second horizontal line might be found by multiplying by 10 or dividing by 1/10.

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All the tables were calculated in this general way by filling in either a vertical or a horizontal line of values, and then deriving all other lines from this one line by division or multiplication.

The values in the tables for Length, Area, Volume and Weight are either exact or incommensurate. The following are exact values:

1 meter	= 39.37 inches.
1 square meter	= 1 549.996 9 square inches.
1 cubic meter	= 61 023:377 853 cubic inches.
1 gallon	= 231 cubic inches.
1 bushel	= 2 150.42 cubic inches.
1 kilogram	= 15 432.356 39 grains.

These values are incommensurate, but are true as far as they are given.

1 kilometer	= 3 289.833 3 feet.
1 inch	= .083 33 feet.
1 mile	= 1.698 347 22 kilometers.

The incommensurate values are carried out to ten places in most cases.

Some of the values in the table of "Pressures" are incommensurate, and some are approximate. The following relations are assumed:

1 atmosphere	= 760 mm. of mercury.
1 cubic inch, water	= .036 062 pounds.
1 cubic inch, mercury	= .491 187 pounds.

These values are approximate, so all values based on them must be approximate.

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MEASURES OF LENGTH.

	Inches.	Feet.	Yards.	Miles.	Millimeters.	Centimeters.	Meters.	Kilometers.
Millimeter	.039 37	.003 280 8	.001 093 6	.000 000 621	1.	.1	.001	.000 001
Centimeter	.393 7	.032 808 3	.010 936 1	.000 006 213	10.	1.	.01	.000 01
Meter	39.37	3.280 833	1.093 611	.000 621 369	1 000.	100.	1.	.001
Kilometer	39 370.	3 280.833	1 093.611	.621 369 949	1 000 000.	100 000.	1 000.	1.
Mil	.001	.000 083 3	.000 027 7	.000 000 015	.025 400 050	.002 540 005	.000 025 400	.000 000 025
Inch	1.	.083 333 3	.027 777 7	.000 015 783	25.400 050 8	2.540 005 08	.025 400 050	.000 025 400
Foot	12.	1.	.333 333 3	.000 189 394	304.800 610	30.480 061 0	.304 800 610	.000 304 800
Yard	36.	3.	1.	.000 568 182	914.401 829	91.440 182 9	.914 401 829	.000 914 401
Rod	198.	16.5	5.5	.003 125	5 029.210 06	502.921 006	5.029 210 06	.005 029 210
Mile	63 360.	5 280.	1 760.	1.	1 609 347.22	160 934.722	1 609.347 22	1.609 347 22
Link	7.92	.66	.22	.000 125	201.168 402	20.116 840 2	.201 168 402	.000 201 168
Chain	792.	66.	22.	.012 5	20 116.840 2	2 011.684 02	20.116 840 2	.020 116 840
Naut. mile	72 962.4	6 080.2	2 026.733	1.151 553 03	1 853 248.67	185 324.867	1 853.248 67	1.853 248 67

Derived from 1 meter = 39.37 inches.

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MEASURES OF AREA.

	Circular mils.	Square inches.	Square feet.	Square yards.	Square rods.	Acres.	Square millimeters.
Cir. mm.	1 549.996 900	.001 217 364 7	.000 008 453 9	.000 000 939 3	.000 000 031 1		.785 398 163 4
Sq. mm.	1 973.517 347	.001 549 996 9	.000 010 763 8	.000 001 195 9	.000 000 039 5		1.
Sq. cm.	197 351.734 7	.154 999 690 0	.001 076 386 7	.000 119 598 5	.000 003 953 7		100.
Sq. meter		*1549.996 900	10.763 867 36	1.195 985 262	.039 536 702 8	.000 247 104 3	1 000 000.
Are		154 999.690 0	1 076.386 736	119.598 526 2	3.953 670 289	.024 710 439 3	100 000 000.
Hectare		15 499 969.00	107 638.673 6	11 959.852 62	395.367 028 9	2.471 043 930	
Sq. Km.		1 549 996 900.	10 763 867.36	1 195 985.262	39 536.7028 9	247.104 393 0	
Circular mil	1.	.000 000 785 4	.000 000 005 5	.000 000 000 6			.000 506 709 5
Square mil	1.273 239 545	.000 001.	.000 000 006 9	.000 000 000 8			.000 645 162 6
Cir. inch	1 000 000.	.785 398 163 4	.005 454 153 9	.000 606 017 1	.000 020 033 6	.000 000 125 2	506.709 505 9
Sq. inch	1 273 239.545	1.	.006 944 444 4	.000 771 604 9	.000 025 507 6	.000 000 159 4	645.162 580 6
Sq. foot		144.	1.	.111 111 111 1	.003 673 094 6	.000 022 956 8	92 903.411 61
Square yard		1 296.	9.	1.	.033 057 851 2	.000 206 611 5	836 130.704 5
Square rod		39 204.	272.25	30.25	1.	.006 25	25 292 953.81
Acre		6 272 640.	43 560.	4 840.	160.	1.	4 046 872 610.
Sq. mile		4 014 489 600.	27 878 400.	3 097 600.	102 400.	640.	

Square mils = Square inches with decimal point six places to the right.
Square centimeter = Square millimeter with decimal point two places to the left.
Square meter = Square millimeter with decimal point six places to the left.
Hectare = Square millimeter with decimal point ten places to the left.

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MEASURES OF VOLUME.

	Cubic inches.	Cubic feet.	Cubic yards.	Gallons.	Bushels.	Cubic centimeters.	Liters.
Cu. cm	.061 023 377 9	.000 035 314 4	.000 001 307 9	.000 264 170 4	.000 028 377 4	1.	.000 999 973
Liter	61.025 025 53	.035 315 408 3	.001 307 978 1	.264 177 599 7	.028 378 189 2	1 000.027	1.
Hectoliter	6 102.502 553	3.531 540 83	.130 797 808 5	26.417 759 97	2.837 818 916	100 002.7	100.
Cubic meter	*61 023.377 95	35.314 454 83	1.307 942 772	264.170 467 3	28.377 422 99	1 000 000.	999.973 000 7
Cubic inch	1.	.000 578 703 7	.000 021 433 5	.004 329 004 3	.000 465 025 4	16.387 162 32	.016 386 719 9
Cubic foot	1 728.	1.	.037 037 037 0	7.480 519 481	.803 563 954 9	28 317.016 49	28.316 251 98
Cubic yard	46 656.	27.	1.	201.974 026 0	21.696 226 78	764 559.445 3	764.538 803 4
Pint, liquid	28.875	.016 710 069 4	.000 618 891 5	.125	.013 427 609 5	473.179 312 1	.473 166 536 9
Quart	57.75	.033 420 138 9	.001 237 782 9	.25	.026 855 219 0	946.358 624 1	.946 333 073 9
Gallon	*231.	.133 680 555 6	.004 951 131 7	1.	.107 420 875 7	3 785.434 497	3.785 332 296
Pint, dry	33.600 312 5	.019 444 625 3	.000 720 171 3	.145 455 898 3	.015 625	550.613 775 0	.550 598 909 4
Quart	67.200 625	.038 889 250 6	.001 440 342 6	.290 911 796 5	.031 25	1 101.227 550	1.101 197 819
Peck	537.605	.311 114 004 6	.011 522 740 9	2.327 294 372	.25	8 809.820 401	8.809 582 550
Bushel	*2 150.42	1.244 456 019	.046 090 963 7	9.309 177 489	1.	35 239.281 60	35.238 330 20

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MEASURES OF WEIGHT.

	Grains.	*Ounces, troy.	Pounds, troy.	Ounces, avoirdupois.	Pounds, avoirdupois.	Grams.	Kilograms.
Milligram	.015 432 356 3	.000 032 150 7	.000 002 679 2	.000 035 273 9	.000 002 204 6	.001	.000 001
Gram	15.432 356 39	.032 150 742 4	.002 679 228 5	.035 273 957 4	.002 204 622 3	1.	.001
Kilogram *	15 432.356 39	32.150 742 48	2.679 228 540	35.273 957 46	2.204 622 341	1 000.	1.
Metric ton	15 432 356.39	32 150.742 48	2 679.228 540	35 273.957 46	2 204.622 341	1 000 000.	1 000.
Grain	1.	.002 083 333 3	.000 173 611 1	.002 285 714 3	.000 142 857 1	.064 798 918 2	.000 064 798 9
Ounce, troy	480.	1.	.083 333 333 3	1.097 142 857	.068 571 428 6	31.103 480 76	.031 103 480 7
Pound, troy	5 760.	12.	1.	13.165 714 29	.822 857 142 9	373.241 769 1	.373 241 769 1
Ounce, av.	437.5	.911 458 333 3	.075 954 861 1	1.	.062 5	28.349 526 73	.028 349 526 7
Pound, av.	7 000.	14.583 333 33	1.215 277 777	16.	1.	453.592 427 7	.453 592 427 7
Ton	14 000 000.	29 166.666 66	2 430.555 555	32 000.	2 000.	907 184.855 4	907.184 855 4
Ton, long	15 680 000.	32 666.666 66	2 722.222 222	35 840.	2 240.	1 016 047.038	1 016.047 038

Milligrams = Grams with decimal point three places to the right, 1.

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PRESSURE.

	Atmospheres.	Pounds per square inch.	Pounds per square foot.	Inches of mercury.	Millimeters of mercury.	Feet of water at 68° F.	Kilograms per square mm.	Kilograms per square meter.
Atmosphere	1.	14.696 9	2 116.35	29.921 2	760.	33.962 2	.010 332 9	10 332.9
Pound per square inch	.068 041 5	1.	144.	2.035 88	51.711 6	2.310 84	.000 703 067	703.067
Pound per square foot	.000 472 511	.006 944 44	1.	.014 138 1	.359 108	.016 047 5	.000 004 882 4	4.882 41
Inch of mercury	.033 421 1	.491 187	70.730 9	1.	25.400 1	1.135 05	.000 345 337	345.337 3
Millimeter of mercury	.001 315 79	.019 338 0	2.784 68	.039 37	1.	.044 687 1	.000 013 595 9	13.595 9
Foot of water at 68°	.029 444 5	.432 743	62.315	.881 015	22.377 8	1.	.000 304 247	304.247
Kilogram per square mm.	96.778 2	1 422.34	204 817.	2 895.72	73 551.4	3 286.80	1.	1 000 000.
Kilogram per sq. meter	.000 096 778 2	.001 422 34	.204 817	.002 895 72	.073 551 4	.003 286 80	.000 001	1.

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WEIGHTS AND LENGTHS.

	Kilograms per kilometer.	Grains per inch.	Pounds per 1000 feet.	Pounds per mile.	Grains per 120 yards.	Grams per 120 yards.	Grams per foot.
Dyne per centimeter	.101 978 734 2	.039 973 893 1	.068 526 673 9	.361 820 837 8	172.687 218 1	11.189 944 93	.031 083 180 3
Gram per centimeter	100.	39.198 263 63	67.197 023 36	354.800 283 1	169 336.498 9	10 972.821 95	30.480 060 96
Kilogram per kilometer	1.	.391 982 636 3	.671 970 233 6	3.548 002 831	1 693.364 989	109.728 219 5	.304 800 609 6
Grain per inch	2.551 133 411	1.	1.714 285 714	9.051 428 571	4 320.	279.931 236 8	.777 587 018 9
Pound per yard	496.053 718 8	194.444 444 4	333.333 333 3	1 760.	840 000.	54 431.091 32	151.197 475 9
Pound per 1000 feet	1.488 161 157	.583 333 333 3	1.	5.28	2 520.	163.293 274 8	.453 592 427 7
Pound per mile	.281 848 703 9	.110 479 797 9	.189 393 939 3	1.	477.272 727 2	30.926 756 43	.085 907 656 8
Grain per 120 yards	.000 590 540 1	.000 231 481 5	.000 396 825 4	.002 095 238 1	1.	.064 798 918 2	.000 179 997 0
Gram per 120 yards	.009 113 425 9	.003 572 304 7	.006 123 950 9	.032 334 461 0	15.432 356 39	1.	.002 777 777 7
Pound per 120 yards	4.133 780 990	1.620 370 370	2.777 777 777	14.666 666 66	7 000.	453.592 427 7	1.259 978 966
Gram per foot	3.280 833 333	1.286 029 699	2.204 622 341	11.640 405 96	5 555.648 300	360.	1.

Grams per centimeter = Kilograms per kilometer with decimal point two places to the left.
Grams per meter = Kilograms per kilometer.

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WEIGHTS AND VOLUMES.

	Grains per cubic inch.	Pounds per cubic inch.	Pounds per cubic foot.	Pounds per cubic yard.	Pounds per gallon.	Pounds per bushel.	Grams per cubic cm.
Grain per cubic inch	1	.000 142 8570	.246 857 1429	6.665 142 855	.033	.307 202 8572	.003 954 2489
Grain per cubic foot	.000 578 7037	.000 000 0827	.000 142 8571	.003 857 1429	.000 019 0972	.000 177 7794	.000 002 2883
Pound per cubic inch	7000	1	1728	46 656	231	2 150.42	27.679 742 14
Pound per cubic foot	4.050 925 926	.000 578 7037	1	27	.133 680 5556	1.244 456 019	.016 018 3693
Pound per cubic yard	.150 034 2936	.000 021 4335	.037 037 0370	1	.004 951 1317	.046 090 9637	.000 593 2729
Pound per gallon	30.303 030 30	.004 329 0043	7.480 519 480	201.974 0259	1	9.309 177 490	.119 825 7236
Pound per bushel	3.255 178 058	.000 465 0254	.803 563 9549	21.696 226 78	.107 420 8759	1	.012 871 7842
Gram per cubic cm.	252.892 5292	.036 127 5042	62.428 327 21	1 685.564 834	8.345 453 464	77.689 307 52	1
Kilogram per cubic meter	.252 892 5292	.000 036 1275	.062 428 3272	1.685 565 257	.008 345 4534	.077 689 3270	.001

Kilogram per liter = Gram per cubic centimeter.

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MILLIMETERS TO MILS.

	0	1	2	3	4	5	6	7	8	9
0		39.4	78.7	118.1	157.5	196.9	236.2	275.6	315.0	354.3
1	393.7	433.1	472.4	511.8	551.2	590.6	629.9	669.3	708.7	748.0
2	787.4	826.8	866.1	905.5	944.9	984.3	1 023.6	1 063.0	1 102.4	1 141.7
3	1 181.1	1 220.5	1 259.8	1 299 2	1 338.6	1 378.0	1 417.3	1 456.7	1 496.1	1 535.4
4	1 574.8	1 614.2	1 653.5	1 692.9	1 732 3	1 771.7	1 811.0	1 850.4	1 889.8	1 929.1
5	1 968.5	2 007.9	2 047.2	2 086.6	2 126.0	2 165.4	2 204.7	2 244.1	2 283.5	2 322.8
6	2 362.2	2 401.6	2 440.9	2 480.3	2 519.7	2 559.1	2 598.4	2 637.8	2 677.2	2 716.5
7	2 755.9	2 795.3	2 834.6	2 874.0	2 913.4	2 952.8	2 992.1	3 031.5	3 070.9	3 110.2
8	3 149.6	3 189.0	3 228.3	3 267.7	3 307.1	3 346.5	3 385.8	3 425.2	3 464.6	3 503.9
9	3 543.3	3 582.7	3 622.0	3 661.4	3 700.8	3 740.2	3 779.5	3 818.9	3 858.3	3 897.6
10	3 937.0	3 976.4	4 015.7	4 055.1	4 094.5	4 133.9	4 173.2	4 212.6	4 252.0	4 291.3
11	4 330.7	4 370.1	4 409.4	4 448.8	4 488.2	4 527.6	4 566.9	4 606.3	4 645.7	4 685.0
12	4 724.4	4 763.8	4 803.1	4 842.5	4 881.9	4 921.3	4 960.6	5 000.0	5 039.4	5 078.7
13	5 118.1	5 157.5	5 196.8	5 236.2	5 275.6	5 315.0	5 354.3	5 393 7	5 433.1	5 472.4
14	5 511.8	5 551.2	5 590.5	5 629.9	5 669.3	5 708.7	5 748.0	5 787 4	5 826.8	5 866.1
15	5 905.5	5 944.9	5 984.2	6 023.6	6 063.0	6 102.4	6 141.7	6 181.1	6 220.5	6 259.8
16	6 299.2	6 338 6	6 377.9	6 417.3	6 456.7	6 496.1	6 535.4	6 574.8	6 614.2	6 653.5
17	6 692.9	6 732 3	6 771.6	6 811.0	6 850.4	6 889.8	6 929.1	6 968.5	7 007.9	7 047.2
18	7 086.6	7 126.0	7 165.3	7 204.7	7 244.1	7 283.5	7 322.8	7 362.2	7 401.6	7 440.9
19	7 480.3	7 519.7	7 559.0	7 598.4	7 637.8	7 677.2	7 716.5	7 755.9	7 795.3	7 834.6

1 millimeter = 39.37 mils.

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MILLIMETERS TO MILS.

	0	1	2	3	4	5	6	7	8	9
20	7 874	7 913	7 953	7 992	8 031	8 071	8 110	8 150	8 189	8 228
21	8 268	8 307	8 346	8 386	8 425	8 465	8 504	8 543	8 583	8 622
22	8 661	8 701	8 740	8 780	8 819	8 858	8 898	8 937	8 976	9 016
23	9 055	9 094	9 134	9 173	9 213	9 252	9 291	9 331	9 370	9 409
24	9 449	9 488	9 528	9 567	9 606	9 646	9 685	9 724	9 764	9 803
25	9 843	9 882	9 921	9 961	10 000	10 039	10 079	10 118	10 157	10 197
26	10 236	10 276	10 315	10 354	10 394	10 433	10 472	10 512	10 551	10 591
27	10 630	10 669	10 709	10 748	10 787	10 827	10 866	10 905	10 945	10 984
28	11 024	11 063	11 102	11 142	11 181	11 220	11 260	11 299	11 339	11 378
29	11 417	11 457	11 496	11 535	11 575	11 614	11 654	11 693	11 732	11 772
30	11 811	11 850	11 890	11 929	11 968	12 008	12 047	12 087	12 126	12 165
31	12 205	12 244	12 283	12 323	12 362	12 402	12 441	12 480	12 520	12 559
32	12 598	12 638	12 677	12 717	12 756	12 795	12 835	12 874	12 913	12 953
33	12 992	13 031	13 071	13 110	13 150	13 189	13 228	13 268	13 307	13 346
34	13 386	13 425	13 465	13 504	13 543	13 583	13 622	13 661	13 701	13 740
35	13 780	13 819	13 858	13 898	13 937	13 976	14 016	14 055	14 094	14 134
36	14 173	14 213	14 252	14 291	14 331	14 370	14 409	14 449	14 488	14 528
37	14 567	14 606	14 646	14 685	14 724	14 764	14 803	14 842	14 882	14 921
38	14 961	15 000	15 039	15 079	15 118	15 157	15 197	15 236	15 276	15 315
39	15 354	15 394	15 433	15 472	15 512	15 551	15 591	15 630	15 669	15 709

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MILS TO MILLIMETERS.

	0	1	2	3	4	5	6	7	8	9
0		.025	.051	.076	.102	.127	.152	.178	.203	.229
1	.254	.279	.305	.330	.356	.381	.406	.432	.457	.483
2	.508	.533	.559	.584	.610	.635	.660	.686	.711	.737
3	.762	.787	.813	.838	.864	.889	.914	.940	.965	.991
4	1.016	1.041	1.067	1.092	1.118	1.143	1.168	1.194	1.219	1.245
5	1.270	1.295	1.321	1.346	1.372	1.397	1.422	1.448	1.473	1.499
6	1.524	1.549	1.575	1.600	1.626	1.651	1.676	1.702	1.727	1.753
7	1.778	1.803	1.829	1.854	1.880	1.905	1.930	1.956	1.981	2.007
8	2.032	2.057	2.083	2.108	2.134	2.159	2.184	2.210	2.235	2.261
9	2.286	2.311	2.337	2.362	2.388	2.413	2.438	2.464	2.489	2.515
10	2.540	2.565	2.591	2.616	2.642	2.667	2.692	2.718	2.743	2.769
11	2.794	2.819	2.845	2.870	2.896	2.921	2.946	2.972	2.997	3.023
12	3.048	3.073	3.099	3.124	3.150	3.175	3.200	3.226	3.251	3.277
13	3.302	3.327	3.353	3.378	3·404	3.429	3.454	3.480	3 505	3.531
14	3.556	3.581	3.607	3.632	3.658	3.683	3.708	3.734	3.759	3.785
15	3.810	3.835	3.861	3.886	3.912	3.937	3.962	3.988	4.013	4.039
16	4.064	4.089	4.115	4.140	4.166	4.191	4.216	4.242	4.267	4.293
17	4.318	4.343	4.369	4.394	4.420	4.445	4.470	4.496	4.521	4.547
18	4.572	4.597	4.623	4.648	4.674	4,699	4.724	4.750	4.775	4.801
19	4.826	4.851	4.877	4.902	4.928	4.953	4.978	5.004	5.029	5.055

1 mil = .025 400 050 8 millimeters.

MILS TO MILLIMETERS.

	0	1	2	3	4	5	6	7	8	9
20	5.080	5.105	5.131	5.156	5.182	5.207	5.232	5.258	5.283	5.309
21	5.334	5.359	5.385	5.410	5.436	5.461	5.486	5.512	5.537	5.563
22	5.588	5.613	5.639	5.664	5.690	5.715	5.740	5.766	5.791	5.817
23	5.842	5.867	5.893	5.918	5.944	5.969	5.994	6.020	6.045	6.071
24	6.096	6.121	6.147	6.172	6.198	6.223	6.248	6.274	6.299	6.325
25	6.350	6.375	6.401	6.426	6.452	6.477	6.502	6.528	6.553	6.579
26	6.604	6.629	6.655	6.680	6.706	6.731	6.756	6.782	6.807	6.833
27	6.858	6.883	6.909	6.934	6.960	6.985	7.010	7.036	7.061	7.087
28	7.112	7.137	7.163	7.188	7.214	7.239	7.264	7.290	7.315	7.341
29	7.366	7.391	7.417	7.442	7.468	7.493	7.518	7.544	7.569	7.595
30	7.620	7.645	7.671	7.696	7.722	7.747	7.772	7.798	7.823	7.849
31	7.874	7.899	7.925	7.950	7.976	8.001	8.026	8.052	8.077	8.103
32	8.128	8.153	8.179	8.204	8.230	8.255	8.280	8.306	8.331	8.357
33	8.382	8.407	8.433	8.458	8.484	8.509	8.534	8.560	8.585	8.611
34	8.636	8.661	8.687	8.712	8.738	8.763	8.788	8.814	8.839	8.865
35	8.890	8.915	8.941	8.966	8.992	9.017	9.042	9.068	9.093	9.119
36	9.144	9.169	9.195	9.220	9.246	9.271	9.296	9.322	9.347	9.373
37	9.398	9.423	9.449	9.474	9.500	9.525	9.550	9.576	9.601	9.627
38	9.652	9.677	9.703	9.728	9.754	9.779	9.804	9.830	9.855	9.881
39	9.906	9.931	9.957	9.982	10.008	10.033	10.058	10.084	10.109	10.135

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METERS TO FEET.

	0	1	2	3	4	5	6	7	8	9
0		3.28	6.56	9.84	13.12	16.40	19.69	22.97	26.25	29.53
1	32.808 3	36.09	39.37	42.65	45.93	49.21	52.49	55.77	59.06	62.34
2	65.616 7	68.90	72.18	75.46	78.74	82.02	85.30	88.58	91.86	95.14
3	98.425 0	101.71	104.99	108.27	111.55	114.83	118.11	121.39	124.67	127.95
4	131.233 3	134.51	137.80	141.08	144.36	147.64	150.92	154.20	157.48	160.76
5	164.041 7	167.32	170.60	173.88	177.17	180.45	183.73	187.01	190.29	193.57
6	196.850 0	200.13	203.41	206.69	209.97	213.25	216.54	219.82	223.10	226.38
7	229.658 3	232.94	236.22	239.50	242.78	246.06	249.34	252.62	255.91	259.19
8	262.466 7	265.75	269.03	272.31	275.59	278.87	282.15	285.43	288.71	291.99
9	295.275 0	298.56	301.84	305.12	308.40	311.68	314.96	318.24	321.52	324.80
10	328.083 3	331.36	334.65	337.93	341.21	344.49	347.77	351.05	354.33	357.61
11	360.891 7	364.17	367.45	370.73	374.02	377.30	380.58	383.86	387.14	390.42
12	393.700 0	396.98	400.26	403.54	406.82	410.10	413.39	416.67	419.95	423.23
13	426.508 3	429.79	433.07	436.35	439.63	442.91	446.19	449.47	452.76	456.04
14	459.316 6	462.60	465.88	469.16	472.44	475.72	479.00	482.28	485.56	488.84
15	492.125 0	495.41	498.69	501.97	505.25	508.53	511.81	515.09	518.37	521.65
16	524.933 3	528.21	531.50	534.78	538.06	541.34	544.62	547.90	551.18	554.46
17	557.741 7	561.02	564.30	567.58	570.87	574.15	577.43	580.71	583.99	587.27
18	590.550 0	593.83	597.11	600.39	603.67	606.95	610.24	613.52	616.80	620.08
19	623.358 3	626.64	629.92	633.20	636.48	639.76	643.04	646.32	649.61	662.89

1 Meter = 3.280 833 3+ feet.

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METERS TO FEET.

	0	1	2	3	4	5	6	7	8	9
20	656.1667	659.45	662.73	666.01	669.29	672.57	675.85	679.13	682.41	685.69
21	688.9750	692.26	695.54	698.82	702.10	705.38	708.66	711.94	715.22	718.50
22	721.7833	725.06	728.34	731.63	734.91	738.19	741.47	744.75	748.03	751.31
23	754.5917	757.87	761.15	764.43	767.71	771.00	774.28	777.56	780.84	784.12
24	787.4000	790.68	793.96	797.24	800.52	803.80	807.08	810.37	813.65	816.93
25	820.2083	823.49	826.77	830.05	833.33	836.61	839.89	843.17	846.45	849.74
26	853.0167	856.30	859.58	862.86	866.14	869.42	872.70	875.98	879.26	882.54
27	885.8250	889.11	892.39	895.67	898.95	902.23	905.51	908.79	912.07	915.35
28	918.6333	921.91	925.19	928.48	931.76	935.04	938.32	941.60	944.88	948.16
29	951.4417	954.72	958.00	961.28	964.56	967.85	971.13	974.41	977.69	980.97
30	984.2500	987.53	990.81	994.09	997.37	1 000.65	1 003.93	1 007.22	1 010.50	1 013.78
31	1 017.058	1 020.34	1 023.62	1 026.90	1 030.18	1 033.46	1 036.74	1 040.02	1 043 30	1 046.59
32	1 049.867	1 053.15	1 056.43	1 059.71	1 062.99	1 066.27	1 069.55	1 072.83	1 076.11	1 079.39
33	1 082.675	1 085.96	1 089.24	1 092.52	1 095.80	1 099.08	1 102.36	1 105.64	1 108.92	1 112.20
34	1 115.483	1 118.76	1 122.04	1 125.33	1 128.61	1 131.89	1 135.17	1 138.45	1 141.73	1 145.01
35	1 148.292	1 151.57	1 154.85	1 158.13	1 161.41	1 164.70	1 167.98	1 171.26	1 174.54	1 177.82
36	1 181.100	1 184.38	1 187.66	1 190.94	1 194.22	1 197.50	1 200.78	1 204.07	1 207.35	1 210.63
37	1 213.908	1 217.19	1 220.47	1 223.75	1 227.03	1 230.31	1 233.59	1 236.87	1 240.15	1 276.24
38	1 246.717	1 250.00	1 253.28	1.256.56	1 259.84	1 263.12	1 266.40	1 269.68	1 272.96	1 243.44
39	1 279.525	1 282.81	1 286 09	1 289.37	1 292.65	1 295.93	1 299.21	1 302.49	1 305.77	1 309.05

FEET TO METERS.

	0	1	2	3	4	5	6	7	8	9
0		.304 8	.609 6	.914 4	1.219 2	1.524 0	1.828 8	2.133 6	2.438 4	2.743 2
1	3.048 006	3.352 8	3.657 6	3.962 4	4.267 2	4.572 0	4.876 8	5.181 6	5.486 4	5.791 2
2	6.096 012	6.400 8	6.705 6	7.010 4	7.315 2	7.620 0	7.924 8	8.229 6	8.534 4	8.839 2
3	9.144 018	9.448 8	9.753 6	10.058 4	10.363 2	10.668 0	10.972 8	11.277 6	11.582 4	11.887 2
4	12.192 024	12.496 8	12.801 6	13.106 4	13.411 2	13.716 0	14.020 8	14.325 6	14.630 4	14.935 2
5	15.240 030	15.544 8	15.849 6	16.154 4	16.459 2	16.764 0	17.068 8	17.373 6	17.678 4	17.983 2
6	18.288 037	18.592 8	18.897 6	19.202 4	19.507 2	19.812 0	20.116 8	20.421 6	20.726 4	21.031 2
7	21.336 043	21.640 8	21.945 6	22.250 4	22.555 2	22.860 0	23.164 8	23.469 6	23.774 4	24.079 2
8	24.384 049	24.688 8	24.993 6	25.298 5	25.603 3	25.908 1	26.212 9	26.517 7	26.822 5	27.127 3
9	27.432 055	27.736 9	28.041 7	28.346 5	28.651 3	28.956 1	29.260 9	29.565 7	29.870 5	30.175 3
10	30.480 061	30.784 9	31.089 7	31.394 5	31.699 3	32.004 1	32.308 9	32.613 7	32.918 5	33.223 3
11	33.528 067	33.832 9	34.137 7	34.442 5	34.747 3	35.052 1	35.356 9	35.661 7	35.966 5	36.271 3
12	36.576 073	36.880 9	37.185 7	37.490 5	37.795 3	38.100 1	38.404 9	38.709 7	39.014 5	39.319 3
13	39.624 079	39.928 9	40.233 7	40.538 5	40.843 3	41.148 1	41.452 9	41.757 7	42.062 5	42.367 3
14	42.672 085	42.976 9	43.281 7	43.586 5	43.891 3	44.196 1	44.500 9	44.805 7	45.110 5	45.415 3
15	45.720 091	46.024 9	46.329 7	46.634 5	46.939 3	47.244 1	47.548 9	47.853 7	48.158 5	48.463 3
16	48.768 098	49.072 9	49.377 7	49.682 5	49.987 3	50.292 1	50.596 9	50.901 7	51.206 5	51.511 3
17	51.816 104	52.120 9	52.425 7	52.730 5	53.035 3	53.340 1	53.644 9	53.949 7	54.254 5	54.559 3
18	54.864 110	55.168 9	55.473 7	55.778 5	56.083 3	56.388 1	56.692 9	56.997 7	57 302 5	57.607 3
19	57.912 116	58.216 9	58.521 7	58.826 5	59.131 3	59.436 1	59.740 9	60.045 7	60.350 5	60.655 3

1 Foot =.304 800 609 6 meters.

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FEET TO METERS.

	0	1	2	3	4	5	6	7	8	9
20	60.960 122	61.265	61.570	61.875	62.179	62.484	62.789	63.094	63.399	63.703
21	64.008 128	64.313	64.618	64.923	65.227	65.532	65.837	66.142	66.447	66.751
22	67.056 134	67.361	67.666	67.971	68.275	68.580	68.885	69.190	69.495	69.799
23	70.104 140	70.409	70.714	71.019	71.323	71.628	71.933	72.238	72.543	72.847
24	73.152 146	73.457	73.762	74.067	74.371	74.676	74.981	75.286	75.591	75.895
25	76.200 153	76.505	76.810	77.115	77.419	77.724	78.029	78.334	78.639	78.943
26	79.248 159	79.553	79.858	80.163	80.467	80.772	81.077	81.382	81.687	81.991
27	82.296 165	82.601	82.906	83.211	83.515	83.820	84.125	84.430	84.735	85.039
28	85.344 171	85.649	85.954	86.259	86.563	86.868	87.173	87.478	87.783	88.087
29	88.392 177	88.697	89.002	89.307	89.611	89.916	90.221	90.526	90.831	91.135
30	91.440 183	91.745	92.050	92.355	92.659	92.964	93.269	93.574	93.879	94.183
31	94.488 189	94.793	95.098	95.403	95.707	96.012	96.317	96.622	96.927	97.231
32	97.536 195	97.841	98.146	98.451	98.755	99.060	99.365	99.670	99.975	100.279
33	100.584 201	100.889	101.194	101.499	101.803	102.108	102.413	102.718	103.023	103.327
34	103.632 207	103.937	104.242	104.547	104.851	105.156	105.461	105.766	106.071	106.375
35	106.680 214	106.985	106.290	107.595	107.899	108.204	108.509	108.814	109.119	109.423
36	109.728 220	110.033	110.338	110.643	110.947	111.252	111.557	111.862	112.167	112.471
37	112.776 226	113.081	113.386	113.691	113.995	114.300	114.605	114.910	115.215	115.519
38	115.824 232	116.129	116.434	116.739	117 043	117.348	117.653	117.958	118.263	118.567
39	118.872 238	119.177	119 482	119.787	120.091	120.396	120.701	121 006	121.311	121.615

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KILOGRAMS TO POUNDS AVOIRDUPOIS.

	0	1	2	3	4	5	6	7	8	9
0		2.2	4.4	6.6	8·8	11.0	13.2	15.4	17.6	19.8
1	22.046 2	24.3	26.5	28.7	30.9	33.1	35.3	37.5	39.7	41.9
2	44.092 4	46.3	48.5	50.7	52.9	55.1	57.3	59.5	61.7	63.9
3	66.138 7	68.3	70.5	72.8	75.0	77.2	79.4	81.6	83.8	86.0
4	88.184 9	90.4	92.6	94.8	97.0	99.2	101.4	103.6	105.8	108.0
5	110.231 1	112.4	114.6	116.8	119.0	121.3	123.5	125.7	127.9	130.1
6	132.277 3	134.5	136.7	138.9	141.1	143.3	145.5	147.7	149.9	152.1
7	154.323 6	156.5	158.7	160.9	163.1	165.3	167.6	169.8	172.0	174.2
8	176.369 8	178.6	180.8	183.0	185.2	187.4	189.6	191.8	194.0	196.2
9	198.416 0	200.6	202.8	205.0	207.2	209.4	211.6	213.8	216.1	218.3
10	220.462 2	222.7	224.9	227.1	229.3	231.5	233.7	235.9	238.1	240.3
11	242.508 5	244.7	246.9	249.1	251.3	253.5	255.7	257.9	260.1	262.4
12	264.554 7	266.8	269.0	271.2	273.4	275.6	277.8	280.0	282.2	284.4
13	286.600 9	288.8	291.0	293.2	295.4	297.6	299.8	302.0	304.2	306.4
14	308.647 1	310.9	313.1	315.3	317.5	319.7	321.9	324.1	326.3	328.5
15	330.693 4	332.9	335.1	337.3	339.5	341.7	343.9	346.1	348.3	350.5
16	352.739 6	354.9	357.1	359.4	361.6	363.8	366.0	368.2	370.4	372.6
17	374.785 8	377.0	379.2	381.4	383.6	385.8	388.0	390.2	392.4	394.6
18	396.832 0	399.0	401.2	403.4	405.7	407.9	410.1	412.3	414.5	416.7
19	418.878 2	421.1	423.3	425.5	427.7	429.9	432.1	434.3	436.5	438.7

1 Kilogram = 2.204 622 341 pounds.

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KILOGRAMS TO POUNDS AVOIRDUPOIS.

	0	1	2	3	4	5	6	7	8	9
20	440.924 5	443.1	445 3	447.5	449.7	451.9	454.2	456.4	458.6	460.8
21	462.970 7	465.2	467.4	469.6	471.8	474.0	476.2	478.4	480.6	482.8
22	485.016 9	487.2	489.4	491.6	493.8	496.0	498.2	500.4	502.7	504.9
23	507.063 1	509.3	511.5	513.7	515.9	518.1	520.3	522.5	524.7	526.9
24	529.109 4	531.3	533.5	535 7	537.9	540.1	542.3	544.5	546.7	549.0
25	551.155 6	553.4	555.6	557.8	560.0	562.2	564.4	566.6	568.8	571.0
26	573.201 8	575.4	577.6	579.8	582.0	584.2	586.4	588.6	590.8	593.0
27	595.248 0	597.5	599.7	601.9	604.1	606.3	608.5	610.7	612.9	615.1
28	617.294 3	619.5	621.7	623.9	626.1	628.3	630.5	632.7	634.9	637.1
29	639.340 5	641.5	643.7	646.0	648.2	650.4	652.6	654.8	657.0	659.2
30	661.386 7	663.6	665.8	668.0	670.2	672.4	674.6	676.8	679.0	681.2
31	683.432 9	685.6	687.8	690.0	692.3	694.5	696.7	698.9	701.1	703.3
32	705.479 1	707.7	709.9	712.1	714.3	716.5	718.7	720.9	723.1	725.3
33	727.525 4	729.7	731.9	734.1	736.3	738.5	740.8	743.0	745.2	747.4
34	749.571 6	751.8	754.0	756.2	758.4	760.6	762.8	765.0	767.2	769.4
35	771.617 8	773.8	776.0	778.2	780.4	782.6	784.8	787.1	789.3	791.5
36	793.664 0	795.9	798.1	800.3	802.5	804.7	806.9	809.1	811.3	813.5
37	815.710 3	817.9	820.1	822.3	824.5	826.7	828.9	831.1	833.3	835.6
38	837.756 5	840.0	842.2	844.4	846.6	848.8	851.0	853.2	855.4	857.6
39	859.802 7	862 0	864.2	866.4	868.6	870.8	873.0	875.2	877.4	879.6

POUNDS AVOIRDUPOIS TO KILOGRAMS.

	0	1	2	3	4	5	6	7	8	9
0		.453 6	.907 2	1.360 8	1.814 4	2.268 0	2.721 6	3.175 1	3.628 7	4.082 3
1	4.535 924	4.989 5	5.443 1	5.896 7	6.350 3	6.803 9	7.257 5	7.711 1	8.164 7	8.618 3
2	9.071 849	9.525 4	9.979 0	10.432 6	10.886 2	11.339 8	11.793 4	12.247 0	12.700 6	13.154 2
3	13.607 773	14.061 4	14.515 0	14.968 6	15.422 1	15.875 7	16.329 3	16.782 9	17.236 5	17.690 1
4	18.143 697	18.597 3	19.050 9	19.504 5	19.958 1	20.411 7	20.865 3	21.318 8	21.772 4	22.226 0
5	22.679 621	23.133 2	23.586 8	24.040 4	24.494 0	24.947 6	25.401 2	25.854 8	26.308 4	26.762 0
6	27.215 546	27.669 1	28.122 7	28.576 3	29.029 9	29.483 5	29.937 1	30.390 7	30.844 3	31.297 9
7	31.751 470	32.205 1	32.658 7	33.112 2	33.565 8	34.019 4	34.473 0	34.926 6	35.380 2	35.833 8
8	36.287 394	36.741 0	37.194 6	37.648 2	38.101 8	38.555 4	39.008 9	39.462 5	39.916 1	40.369 7
9	40.823 318	41.276 9	41.730 5	42.184 1	42.637 7	43.091 3	43.544 9	43.998 5	44.452 1	44.905 7
10	45.359 243	45.812 8	46.266 4	46.720 0	47.173 6	47.627 2	48.080 8	48.534 4	48.988 0	49.441 6
11	49.895 167	50.348 8	50.802 4	51.255 9	51.709 5	52.163 1	52.616 7	53.070 3	53.523 9	53.977 5
12	54.431 091	54.884 7	55.338 3	55.791 9	56.245 5	56.699 1	57.152 6	57.606 2	58.059 8	58.513 4
13	58.967 016	59.420 6	59.874 2	60.327 8	60.781 4	61.235 0	61.688 6	62.142 2	62.595 8	63.049 3
14	63.502 940	63.956 5	64.410 1	64.863 7	65.317 3	65.770 9	66.224 5	66.678 1	67.131 7	67.585 3
15	68.038 864	68.492 5	68.946 0	69.399 6	69.853 2	70.306 8	70.760 4	71.214 0	71.667 6	72.121 2
16	72.574 788	73.028 4	73.482 0	73.935 6	74.389 2	74.842 8	75.296 3	75.749 9	76.203 5	76.657 1
17	77.110 713	77.564 3	78.017 9	78.471 5	78.925 1	79.378 7	79.832 3	80.285 9	80.739 5	81.193 0
18	81.646 637	82.100 2	82.553 8	83.007 4	83.461 0	83.914 6	84.368 2	84.821 8	85.275 4	85.729 0
19	86.182 561	86.636 2	87.089 7	87.543 3	87.996 9	88.450 5	88.904 1	89.357 7	89.811 3	90.264 9

1 Pound = .453 592 427 7 kilos.

Google

POUNDS AVOIRDUPOIS TO KILOGRAMS.

	0	1	2	3	4	5	6	7	8	9
20	90.718 486	91.172	91.626	92.079	92.533	92.986	93.440	93.894	94.347	94.801
21	95.254 410	95.708	96.162	96.615	97.069	97.522	97.976	98.430	98.883	99.337
22	99.790 334	100.244	100.698	101.151	101.605	102.058	102.512	102.965	103.419	103.873
23	104.326 258	104.780	105.233	105.687	106.141	106.594	107.048	107.501	107.955	108.409
24	108.862 183	109.316	109.769	110.223	110.677	111.130	111.584	112.037	112.491	112.945
25	113.398 107	113.852	114.305	114.759	115.212	115.666	116.120	116.573	117.027	117.480
26	117.934 031	118.388	118.841	119.295	119.748	120.202	120.656	121.109	121.563	122.016
27	122.469 956	122.924	123.377	123.831	124.284	124.738	125.192	125.645	126.099	126.552
28	127.005 880	127.459	127.913	128.367	128.820	129.274	129.727	130.181	130.635	131.088
29	131.541 804	131.995	132.449	132.903	133.356	133.810	134.263	134.717	135.171	135.624
30	136.077 728	136.531	136.985	137.439	137.892	138.346	138.799	139.253	139.706	140.160
31	140.613 653	141.067	141.521	141.974	142.428	142.882	143.335	143.789	144.242	144.696
32	145.149 577	145.603	146.057	146.510	146.964	147.418	147.871	148.325	148.778	149.232
33	149.685 501	150.139	150.593	151.046	151.500	151.953	152.407	152.861	153.314	153.768
34	154.221 426	154.675	155.129	155.582	156.036	156.489	156.943	157.397	157 850	158.304
35	158.757 350	159.211	159.665	160.118	160.572	161.025	161.479	161.932	162.386	162.840
36	163.293 274	163.747	164.200	164.654	165.108	165.561	166.015	166.468	166.922	167.376
37	167.829 198	168.283	168.736	169.190	169.644	170.097	170.551	171.004	171.458	171.912
38	172.365 123	172.819	173.272	173.726	174.179	174.633	175.087	175.540	175.994	176.447
39	176.901 047	177.355	177.808	178.262	178.715	179.169	179.623	180.076	180.530	180.983

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KILOGRAMS PER KILOMETER TO POUNDS PER 1000 FEET.

	0	1	2	3	4	5	6	7	8	9
0		.6720	1.344	2.016	2.688	3.360	4.032	4.704	5.376	6.048
1	6.720	7.392	8.064	8.736	9.408	10.08	10.75	11.42	12.10	12.77
2	13.44	14.11	14.78	15.46	16.13	16.80	17.47	18.14	18.82	19.49
3	20.16	20.83	21.50	22.18	22.85	23.52	24.19	24.86	25.53	26.21
4	26.88	27.55	28.22	28.89	29.57	30.24	30.91	31.58	32.25	32.93
5	33.60	34.27	34.94	35.61	36.29	36.96	37.63	38.30	38.97	39.65
6	40.32	40.99	41.66	42.33	43.01	43.68	44.35	45.02	45.69	46.37
7	47.04	47.71	48.38	49.05	49.73	50.40	51.07	51.74	52.41	53.09
8	53.76	54.43	55.10	55.77	56.45	57.12	57.79	58.46	59.13	59.81
9	60.48	61.15	61.82	62.49	63.17	63.84	64.51	65.18	65.85	66.53
10	67.20	67.87	68.54	69.21	69.88	70.56	71.23	71.90	72.57	73.24
11	73.92	74.59	75.26	75.93	76.60	77.28	77.95	78.62	79.29	79.96
12	80.64	81.31	81.98	82.65	83.32	84.00	84.67	85.34	86.01	86.68
13	87.36	88.03	88.70	89.37	90.04	90.72	91.39	92.06	92.73	93.40
14	94.08	94.75	95.42	96.09	96.76	97.44	98.11	98.78	99.45	100.1
15	100.8	101.5	102.1	102.8	103.5	104.2	104.8	105.5	106.2	106.8
16	107.5	108.2	108.9	109.5	110.2	110.9	111.5	112.2	112.9	113.6
17	114.2	114.9	115.6	116.3	116.9	117.6	118.3	118.9	119.6	120.3
18	121.0	121.6	122.3	123.0	123.6	124.3	125.0	125.7	126.3	127.0
19	127.7	128.3	129.0	129.7	130.4	131.0	131.7	132.4	133.1	133.7

1 kilogram per kilometer = .671 970 233 6 pounds 1 000 feet.

KILOGRAMS PER KILOMETER TO POUNDS PER 1000 FEET.

	0	1	2	3	4	5	6	7	8	9
20	134.4	135.1	135 7	136.4	137.1	137.8	138.4	139.1	139.8	140.4
21	141.1	141.8	142.5	143.1	143.8	144.5	145.1	145.8	146.5	147.2
22	147.8	148.5	149.2	149.8	150.5	151.2	151.9	152.5	153·2	153.9
23	154.6	155.2	155.9	156.6	157.2	157.9	158.6	159.3	159.9	160.6
24	161.3	161.9	162.6	163 3	164.0	164.6	165.3	166.0	166.6	167.3
25	168.0	168.7	169.3	170.0	170.7	171.4	172.0	172.7	173.4	174.0
26	174.7	175.4	176.1	176.7	177.4	178.1	178.7	179.4	180.1	180.8
27	181.4	182.1	182.8	183.4	184.1	184.8	185.5	186.1	186.8	187.5
28	188.2	188.8	189.5	190.2	190.8	191.5	192.2	192.9	193.5	194.2
29	194.9	195.5	196.2	196.9	197.6	198.2	198.9	199.6	200.2	200.9
30	201.6	202.3	202.9	203.6	204.3	205.0	205.6	206.3	207.0	207.6
31	208.3	209.0	209.7	210.3	211.0	211.7	212.3	213.0	213.7	214.4
32	215.0	215.7	216.4	217.0	217.7	218.4	219.1	219.7	220.4	221.1
33	221.8	222.4	223.1	223.8	224.4	225.1	225.8	226.5	227.1	227.8
34	228.5	229.1	229.8	230.5	231.2	231.8	232.5	233.2	233.8	234.5
35	235.2	235.9	236.5	237.2	237.9	238.5	239.2	239.9	240.6	241.2
36	241.9	242.6	243.3	243 9	244.6	245.3	245.9	246.6	247.3	248.0
37	248.6	249.3	250.0	250.6	251.3	252.0	252.7	253.3	254.0	254.7
38	255.3	256.0	256.7	257.4	258.0	258.7	259.4	260.1	260.7	261.4
36	262.1	262.7	263.4	264.1	264.8	265.4	266.1	266.8	267.4	268.1

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KILOGRAMS PER SQUARE MILLIMETERS TO POUNDS PER SQUARE INCH.

	0	1	2	3	4	5	6	7	8	9
0		1 422	2 845	4 267	5 689	7 112	8 534	9 956	11 379	12 801
1	14 223	15 646	17 068	18 490	19 913	21 335	22 757	24 180	25 602	27 024
2	28 447	29 869	31 291	32 714	34 136	35 558	36 981	38 403	39 826	41 248
3	42 670	44 093	45 515	46 937	48 360	49 782	51 204	52 627	54 049	55 471
4	56 894	58 316	59 738	61 161	62 583	64 005	65 428	66 850	68 272	69 695
5	71 117	72 539	73 962	75 384	76 806	78 229	79 651	81 073	82 496	83 918
6	85 340	86 763	88 185	89 607	91 030	92 452	93 874	95 297	96 719	98 141
7	99 564	100 986	102 408	103 831	105 253	106 675	108 098	109 520	110 943	112 365
8	113 787	115 210	116 632	118 054	119 477	120 899	122 321	123 744	125 166	126 588
9	128 011	129 433	130 855	132 278	133 700	135 122	136 545	137 967	139 389	140 812
10	142 234	143 656	145 079	146 501	147 923	149 346	150 768	152 190	153 613	155 035
11	156 457	157 880	159 302	160 724	162 147	163 569	164 991	166 414	167 836	169 258
12	170 681	172 103	173 525	174 948	176 370	177 792	179 215	180 637	182 059	183 482
13	184 904	186 327	187 749	189 171	190 594	192 016	193 438	194 861	196 283	197 705
14	199 128	200 550	201 972	203 395	204 817	206 239	207 662	209 084	210 506	211 929
15	213 351	214 773	216 196	217 618	219 040	220 463	221 885	223 307	224 730	226 152
16	227 574	228 997	230 419	231 841	233 264	234 686	236 108	237 531	238 953	240 375
17	241 798	243 220	244 642	246 065	247 487	248 909	250 332	251 754	253 176	254 599
18	256 021	257 444	258 866	260 288	261 711	263 133	264 555	265 978	267 400	268 822
19	270 245	271 667	273 089	274 512	275 934	277 356	278 779	280 201	281 623	283 046

1 Kilogram per square millimeter = 1 422.339 838 9 pounds per square inch.
1 pound per square inch = .000 703 066 856 9 kilogram per square millimeter.

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KILOGRAMS PER SQUARE MILLIMETERS TO POUNDS PER SQUARE INCH.

	0	1	2	3	4	5	6	7	8	9
20	284 468	285 890	287 313	288 735	290 157	291 580	293 002	294 424	295 847	297 269
21	298 691	300 114	301 536	302 958	304 381	305 803	307 225	308 648	310 070	311 492
22	312 915	314 337	315 759	317 182	318 604	320 026	321 449	322 871	324 293	325 716
23	327 138	328 561	329 983	331 405	332 828	334 250	335 672	337 095	338 517	339 939
24	341 362	342 784	344 206	345 629	347 051	348 473	349 896	351 318	352 740	354 163
25	355 585	357 007	358 430	359 852	361 274	362 697	364 119	365 541	366 964	368 386
26	369 808	371 231	372 653	374 075	375 498	376 920	378 342	379 765	381 187	382 609
27	384 032	385 454	386 876	388 299	389 721	391 143	392 566	393 988	395 410	396 833
28	398 255	399 677	401 100	402 522	403 945	405 367	406 789	408 212	409 634	411 056
29	412 479	413 901	415 323	416 746	418 168	419 590	421 013	422 435	423 857	425 280
30	426 702	428 124	429 547	430 969	432 391	433 814	435 236	436 658	438 081	439 503
31	440 925	442 348	443 770	445 192	446 615	448 037	449 459	450 882	452 304	453 726
32	455 149	456 571	457 993	459 416	460 838	462 260	463 683	465 105	466 527	467 950
33	469 372	470 794	472 217	473 639	475 062	476 484	477 906	479 329	480 751	482 173
34	483 596	485 018	486 440	487 863	489 285	490 707	492 130	493 552	494 974	496 397
35	497 819	499 241	500 664	502 086	503 508	504 931	506 353	507 775	509 198	510 620
36	512 042	513 465	514 887	516 309	517 732	519 154	520 576	521 999	523 421	524 843
37	526 266	527 688	529 110	530 533	531 955	533 377	534 800	536 222	537 644	539 067
38	540 489	541 911	543 334	544 756	546 178	547 601	549 023	550 446	551 868	553 290
39	554 713	556 135	557 557	558 980	560 402	561 824	563 247	564 669	566 091	567 514

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WORK OR ENERGY.

Force.

A force is measured by the rate of change of momentum it is capable of producing. The common British unit is the "poundal," the force which in one second retards or accelerates the velocity of a mass of one pound by one foot per second. When grammes, centimeters and seconds are the corresponding units, the unit of force is called the dyne. The poundal and dyne are related as follows:

1 poundal = 13 825.5 dynes.

The unit of force is taken as the weight of or downward force exerted by the earth upon the mass of a standard piece of metal, such as the standard pound or kilogram. Dividing the weight, which is proportional to the mass of the body, by the mass, we find that the acceleration experienced by all bodies at a given place is the same. The value of this acceleration is denoted by g, and it varies from 978.1 at the equator to 983.1 at the poles. By international agreement the value

$$g = 980.665 \frac{\text{cm}}{\text{sec.}^2}$$

$$g = 32.173\,9 \frac{\text{feet}}{\text{sec.}^2}$$

has been chosen as the standard value of the acceleration due to gravity; this value of g may be called the "gravitational acceleration constant." The value 980.665 was chosen to represent the value of g at 45° latitude, and sea level. The force of gravity acting on one gram is 980.665 dynes.

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Heat Units.

A calorie is the quantity of heat required to raise one gram of water one degree C. The mean small calorie is the one-hundredth part of the heat required to raise the temperature of one gram of water from 0° C to 100° C at 760 mm mercury pressure. The experimentally determined relation between the mean small calorie and the erg, is,

$$1 \text{ mean small calorie} = 4.1834 \times 10^7 \text{ ergs}$$

The British Thermal Unit (B. T. U.) is the $1/180$th part of the heat required to raise the temperature of one pound of water from 32° F to 212° F at 760 mm mercury pressure.

Work.

Whenever the point of application of a force moves in the direction of the force, the force is said to do work, and the amount is measured by the product of the force and the distance displaced. The work done by a force of one dyne working through a distance of one centimeter is called the "erg." The erg is, for most purposes, an inconveniently small unit, representing, as it does, the amount of work necessary to lift about $1/980$ gram one centimeter against the attraction of the earth. A more suitable unit is the "joule" which is about one-tenth of the kilogram-meter. A joule equals 10^7 ergs. The foot-pound is the work done by a force of one pound acting through a distance of one foot.

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Power.

Power is defined as the time rate of doing work. The C. G. S. unit of power is one erg per second. The practical unit corresponding to the joule is the watt.

"Watt" equals one joule per second.

"Horse power" equals 550 foot-pounds per second.

Mass.

Mass is the amount of matter in a body and is always constant, but we compare the mass of one body with the mass of another body by means of the force which gravity exerts on those bodies. Scales and balances are all constructed to measure the force of gravity acting on bodies to be compared with know standards.

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MEASURES OF WORK.

	Ergs.	Gram-Centimeters.	Kilogram-Meters.	Gram-Degrees-Centigrade.	Pound-Degrees-Fahrenheit.	Foot-Pounds.	H. P.-Seconds-English.
Erg	1	.001 019 720	$.101\ 972 \times 10^{-7}$	$.239\ 040 \times 10^{-7}$	$.948\ 587 \times 10^{-10}$	$.737\ 561 \times 10^{-7}$	$.134\ 102 \times 10^{-9}$
g-cm	*980.665	1	.000 01	.000 023 441	.000 009 093	.000 072 330	.000 000 131
kg.m	98 066 500	100 000	1	2.344 18	.009 302 46	7.2330	.013 150 9
g-deg.-C	*41 834 000	42 658.8	.426 588	1	.003 968 32	3.085 510	.005 610 02
kg-deg.-C	41 834 000 000	42 658 800	426.588	1 000	3.968 32	3 085.51	5.610 02
lb.-deg.-C	18 975 600 000	19 349 700	193.497	453.592	1.8	1 399.56	2.544 66
lb.-deg.-F	10 542 000 000	10 749 800	107.498	251.996	1	777.536	1.413 70
ft.-lb.	13 558 200	13 825.5	.138 255	.324 095	.001 286 11	1	.001 818 18
H.P.-sec.-English	7 457 010 000	7 604 040	76.040 4	178.252	.707 363	*550	1
H.P.-sec. Metric	7 354 990 000	7 500 000	*75	175.814	.697 685	542.475	.986 318
Joule	10 000 000	10 197.2	.101 972	.239 040	.000 948 587	.737 561	.001 341 02
K. W.-hour	36×10^{12}	36.71×10^{9}	367 100	860 544.	3 414.91	2 655 218	4 827.67

Joule = volt-coulomb = watt for one second.

Calorie = gram degree Centigrade.

B. T. U. = British Thermal Unit = pound-degree Fahrenheit.

AREA OF CIRCLES.

The square of the diameter of a circle expressed in mils gives its area in circular mils, and expressed in millimeters its area in circular millimeters. The diameter squared multiplied by .7854 gives the area in square mils or square millimeters, depending on the units used.

1,000,000 square mils = 1 square inch.
1,000,000 square millimeter = 1 square meter.

The two tables following give the area of a wire in circular mils, square mils, square inches, circular millimeters or square millimeters.

Diameter wire, 253 mils.
Area " 64,009 circular mils.
" " 50 272.6 square mils.
" " .050 272 6 square inches.

Diameter wire, 5.19 millimeters.
Area " 26.9361 circular millimeters,
" " 21.155 56 square millimeters.

These tables are especially useful in getting the breaking weight per square inch, or per square millimeter from the breaking weight of a given wire, or, conversely, to find the breaking weight of a certain wire when the breaking weight per square inch or per square millimeter is given.

If a wire 253 mils in diameter break at 2500 pounds, the breaking weight per square inch is 2500 ÷ .050 272 6 or 49,728 pounds.

If a wire 253 mils in diameter has a breaking strength of 50,000 pounds per square inch, then this wire should break at 50,000 × .050 273 or 2,514 pounds.

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SQUARES.

	0	1	2	3	4	5	6	7	8	9
0		1	4	9	16	25	36	49	64	81
1	100	121	144	169	196	225	256	289	324	361
2	400	441	484	529	576	625	676	729	784	841
3	900	961	1 024	1 089	1 156	1 225	1 296	1 369	1 444	1 521
4	1 600	1 681	1 764	1 849	1 936	2 025	2 116	2 209	2 304	2 401
5	2 500	2 601	2 704	2 809	2 916	3 025	3 136	3 249	3 364	3 481
6	3 600	3 721	3 844	3 969	4 096	4 225	4 356	4 489	4 624	4 761
7	4 900	5 041	5 184	5 329	5 476	5 625	5 776	5 929	6 084	6 241
8	6 400	6 561	6 724	6 889	7 056	7 225	7 396	7 569	7 744	7 921
9	8 100	8 281	8 464	8 649	8 836	9 025	9 216	9 409	9 604	9 801
10	10 000	10 201	10 404	10 609	10 816	11 025	11 236	11 449	11 664	11 881
11	12 100	12 321	12 544	12 769	12 996	13 225	13 456	13 689	13 924	14 161
12	14 400	14 641	14 884	15 129	15 376	15 625	15 876	16 129	16 384	16 641
13	16 900	17 161	17 424	17 689	17 956	18 225	18 496	18 769	19 044	19 321
14	19 600	19 881	20 164	20 449	20 736	21 025	21 316	21 609	21 904	22 201
15	22 500	22 801	23 104	23 409	23 716	24 025	24 336	24 649	24 964	25 281
16	25 600	25 921	26 244	26 569	26 896	27 225	27 556	27 889	28 224	28 561
17	28 900	29 241	29 584	29 929	30 276	30 625	30 976	31 329	31 684	32 041
18	32 400	32 761	33 124	33 489	33 856	34 225	34 596	34 969	35 344	35 721
19	36 100	36 481	36 864	37 249	37 636	38 025	38 416	38 809	39 204	39 601

SQUARES.

	0	1	2	3	4	5	6	7	8	9
20	40 000	40 401	40 804	41 209	41 616	42 025	42 436	42 849	43 264	43 681
21	44 100	44 521	44 944	45 369	45 796	46 225	46 656	47 089	47 524	47 961
22	48 400	48 841	49 284	49 729	50 176	50 625	51 076	51 529	51 984	52 441
23	52 900	53 361	53 824	54 289	54 756	55 225	55 696	56 169	56 644	57 121
24	57 600	58 081	58 564	59 049	59 536	60 025	60 516	61 009	61 504	62 001
25	62 500	63 001	63 504	64 009	64 516	65 025	65 536	66 049	66 564	67 081
26	67 600	68 121	68 644	69 169	69 696	70 225	70 756	71 289	71 824	72 361
27	72 900	73 441	73 984	74 529	75 076	75 625	76 176	76 729	77 284	77 841
28	78 400	78 961	79 524	80 089	80 656	81 225	81 796	82 369	82 944	83 521
29	84 100	84 681	85 264	85 849	86 436	87 025	87 616	88 209	88 804	89 401
30	90 000	90 601	91 204	91 809	92 416	93 025	93 636	94 249	94 864	95 481
31	96 100	96 721	97 344	97 969	98 596	99 225	99 856	100 489	101 124	101 761
32	102 400	103 041	103 684	104 329	104 976	105 625	106 276	106 929	107 584	108 241
33	108 900	109 561	110 224	110 889	111 556	112 225	112 896	113 569	114 244	114 921
34	115 600	116 281	116 964	117 649	118 336	119 025	119 716	120 409	121 104	121 801
35	122 500	123 201	123 904	124 609	125 316	126 025	126 736	127 449	128 164	128 881
36	129 600	130 321	131 044	131 769	132 496	133 225	133 956	134 689	135 424	136 161
37	136 900	137 641	138 384	139 129	139 876	140 625	141 376	142 129	142 884	143 641
38	144 400	145 161	145 924	146 689	147 456	148 225	148 996	149 769	150 544	151 321
39	152 100	152 881	153 664	154 449	155 236	156 025	156 816	157 609	158 404	159 201

SQUARES.

	0	1	2	3	4	5	6	7	8	9
40	160 000	160 801	161 604	162 409	163 216	164 025	164 836	165 649	166 464	167 281
41	168 100	168 921	169 744	170 569	171 396	172 225	173 056	173 889	174 724	175 561
42	176 400	177 241	178 084	178 929	179 776	180 625	181 476	182 329	183 184	184 041
43	184 900	185 761	186 624	187 489	188 356	189 225	190 096	190 969	191 844	192 721
44	193 600	194 481	195 364	196 249	197 136	198 025	198 916	199 809	200 704	201 601
45	202 500	203 401	204 304	205 209	206 116	207 025	207 936	208 849	209 764	210 681
46	211 600	212 521	213 444	214 369	215 296	216 225	217 156	218 089	219 024	219 961
47	220 900	221 841	222 784	223 729	224 676	225 625	226 576	227 529	228 484	229 441
48	230 400	231 361	232 324	233 289	234 256	235 225	236 196	237 169	238 144	239 121
49	240 100	241 081	242 064	243 049	244 036	245 025	246 016	247 009	248 004	249 001
50	250 000	251 001	252 004	253 009	254 016	255 025	256 036	257 049	258 064	259 081
51	260 100	261 121	262 144	263 169	264 196	265 225	266 256	267 289	268 324	269 361
52	270 400	271 441	272 484	273 529	274 576	275 625	276 676	277 729	278 784	279 841
53	280 900	281 961	283 024	284 089	285 156	286 225	287 296	288 369	289 444	290 521
54	291 600	292 681	293 764	294 849	295 936	297 025	298 116	299 209	300 304	301 401
55	302 500	303 601	304 704	305 809	306 916	308 025	309 136	310 249	311 364	312 481
56	313 600	314 721	315 844	316 969	318 096	319 225	320 356	321 489	322 624	323 761
57	324 900	326 041	327 184	328 329	329 476	330 625	331 776	332 929	334 084	335 241
58	336 400	337 561	338 724	339 889	341 056	342 225	343 396	344 569	345 744	346 921
59	348 100	349 281	350 464	351 649	352 836	354 025	355 216	356 409	357 604	358 801

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SQUARES.

	0	1	2	3	4	5	6	7	8	9
60	360 000	361 201	362 404	363 609	364 816	366 025	367 236	368 449	369 664	370 881
61	372 100	373 321	374 544	375 769	376 996	378 225	379 456	380 689	381 924	383 161
62	384 400	385 641	386 884	388 129	389 376	390 625	391 876	393 129	394 384	395 641
63	396 900	398 161	399 424	400 689	401 956	403 225	404 496	405 769	407 044	408 321
64	409 600	410 881	412 164	413 449	414 736	416 025	417 316	418 609	419 904	421 201
65	422 500	423 801	425 104	426 409	427 716	429 025	430 336	431 649	432 964	434 281
66	435 600	436 921	438 244	439 569	440 896	442 225	443 556	444 889	446 224	447 561
67	448 900	450 241	451 584	452 929	454 276	455 625	456 976	458 329	459 684	461 041
68	462 400	463 761	465 124	466 489	467 856	469 225	470 596	471 969	473 344	474 721
69	476 100	477 481	478 864	480 249	481 636	483 025	484 416	485 809	487 204	488 601
70	490 000	491 401	492 804	494 209	495 616	497 025	498 436	499 849	501 264	502 681
71	504 100	505 521	506 944	508 369	509 796	511 225	512 656	514 089	515 524	516 961
72	518 400	519 841	521 284	522 729	524 176	525 625	527 076	528 529	529 984	531 441
73	532 900	534 361	535 824	537 289	538 756	540 225	541 696	543 169	544 644	546 121
74	547 600	549 081	550 564	552 049	553 536	555 025	556 516	558 009	559 504	561 001
75	562 500	564 001	565 504	567 009	568 516	570 025	571 536	573 049	574 564	576 081
76	577 600	579 121	580 644	582 169	583 696	585 225	586 756	588 289	589 824	591 361
77	592 900	594 441	595 984	597 529	599 076	600 625	602 176	603 729	605 284	606 841
78	608 400	609 961	611 524	613 089	614 656	616 225	617 796	619 369	620 944	622 521
79	624 100	625 681	627 264	628 849	630 436	632 025	633 616	635 209	636 804	638 401

Google

SQUARES.

	0	1	2	3	4	5	6	7	8	9
80	640 000	641 601	643 204	644 809	646 416	648 025	649 636	651 249	652 864	654 481
81	656 100	657 721	659 344	660 969	662 596	664 225	665 856	667 489	669 124	670 761
82	672 400	674 041	675 684	677 329	678 976	680 625	682 276	683 929	685 584	687 241
83	688 900	690 561	692 224	693 889	695 556	697 225	698 896	700 569	702 244	703 921
84	705 600	707 281	708 964	710 649	712 336	714 025	715 716	717 409	719 104	720 801
85	722 500	724 201	725 904	727 609	729 316	731 025	732 736	734 449	736 164	737 881
86	739 600	741 321	743 044	744 769	746 496	748 225	749 956	751 689	753 424	755 161
87	756 900	758 641	760 384	762 129	763 876	765 625	767 376	769 129	770 884	772 641
88	774 400	776 161	777 924	779 689	781 456	783 225	784 996	786 769	788 544	790 321
89	792 100	793 881	795 664	797 449	799 236	801 025	802 816	804 609	806 404	808 201
90	810 000	811 801	813 604	815 409	817 216	819 025	820 836	822 649	824 464	826 281
91	828 100	829 921	831 744	833 569	835 396	837 225	839 056	840 889	842 724	844 561
92	846 400	848 241	850 084	851 929	853 776	855 625	857 476	859 329	861 184	863 041
93	864 900	866 761	868 624	870 489	872 356	874 225	876 096	877 969	879 844	881 721
94	883 600	885 481	887 364	889 249	891 136	893 025	894 916	896 809	898 704	900 601
95	902 500	904 401	906 304	908 209	910 116	912 025	913 936	915 849	917 764	919 681
96	921 600	923 521	925 444	927 369	929 296	931 225	933 156	935 089	937 024	938 961
97	940 900	942 841	944 784	946 729	948 676	950 625	952 576	954 529	956 484	958 441
98	960 400	962 361	964 324	966 289	968 256	970 225	972 196	974 169	976 144	978 121
99	980 100	982 081	984 064	986 049	988 036	990 025	992 016	994 009	996 004	998 001

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AREAS OF CIRCLES IN SQUARE UNITS.

DIAMETER OF WIRE.

.	0	1	2	3	4	5	6	7	8	9
0		.79	3.14	7.07	12.57	19.64	28.27	38.49	50.27	63.62
1	78.5	95.0	113.1	132.7	153.9	176.7	201.1	227.0	254.5	283.5
2	314.2	346.4	380.1	415.5	452.4	490.9	530.9	572.6	615.8	660.5
3	706.9	754.8	804.3	855.3	907.9	962.1	1 017.9	1 075.2	1 134.1	1 194.6
4	1 256.6	1 320.3	1 385.4	1 452.2	1 520.5	1 590.4	1 661.9	1 734.9	1 809.6	1 885.7
5	1 963.5	2 042.8	2 123.7	2 206.2	2 290.2	2 375.8	2 463.0	2 551.8	2 642.1	2 734.0
6	2 827.4	2 922.5	3 019.1	3 117.3	3 217.0	3 318.3	3 421.2	3 525.7	3 631.7	3 739.3
7	3 848.5	3 959.2	4 071.5	4 185.4	4 300.8	4 417.9	4 536.5	4 656.6	4 778.4	4 901.7
8	5 026.6	5 153.0	5 281 0	5 410.6	5 541.8	5 674.5	5 808.8	5 944.7	6 082.1	6 221.1
9	6 361.7	6 503.9	6 647.6	6 792.9	6 939.8	7 088.2	7 238.2	7 389.8	7 543.0	7 697.7
10	7 854.0	8 011.9	8 171.3	8 332.3	8 494.9	8 659.0	8 824.7	8 992.0	9 160.9	9 331.3
11	9 503.3	9 676.9	9 852.0	10 028.8	10 207.0	10 386.9	10 568.3	10 751.3	10 935.9	11 122.0
12	11 309.7	11 499.0	11 689.9	11 882.3	12 076,3	12 271.9	12 469.0	12 667.7	12 868.0	13 069.8
13	13 273.2	13 478.2	13 684.8	13 892.9	14 102.6	14 313.9	14 526.7	14 741.1	14 957.1	15 174.7
14	15 393.8	15 614.5	15 836.8	16 060.6	16 286.0	16 513.0	16 741.6	16 971.7	17 203.4	17 436.6
15	17 671.5	17 907.9	18 145.8	18 385.4	18 626.5	18 869.2	19 113.5	19 359.3	19 606.7	19 855.7
16	20 106.2	20 358.3	20 612.0	20 867.2	21 124.1	21 382.5	21 642.4	21 904.0	22 167.1	22 431.8
17	22 698.0	22 965.8	23 235.2	23 506.2	23 778.7	24 052.8	24 328.5	24 605.7	24 884.6	25 164.9
18	25 446.9	25 730.4	26 015.5	26 302.2	26 590.4	26 880.3	27 171.6	27 464.6	27 759.1	28 055.2
19	28 352.9	28 652.1	28 952.9	29 255.3	29 559.3	29 864.8	30 171.9	30 480.5	30 790.8	31 102.6

Area $= d^2 \times .7854$

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AREAS OF CIRCLES IN SQUARE UNITS.

DIAMETER OF WIRE.

	0	1	2	3	4	5	6	7	8	9
20	31 415.9	31 730.9	32 047.4	32 365.5	32 685.1	33 006.4	33 329.2	33 653.5	33 979.5	34 307.0
21	34 636.1	34 966.7	35 298.9	35 632.7	35 968.1	36 305.0	36 643.5	36 983.6	37 325.3	37 668.5
22	38 013.3	38 359.6	38 707.6	39 057.1	39 408.1	39 760.8	40 115.0	40 470.8	40 828.1	41 187.1
23	41 547.6	41 909.6	42 273.3	42 638.5	43 005.3	43 373.6	43 743.5	44 115.0	44 488.1	44 862.7
24	45 238.9	45 616.7	45 996.1	46 377.0	46 759.5	47 143.5	47 529.2	47 916.4	48 305.1	48 695.5
25	49 087.4	49 480.9	49 875.9	50 272.6	50 670.8	51 070.5	51 471.9	51 874.8	52 279.2	52 685.3
26	53 092.9	53 502.1	53 912.9	54 325.2	54 739.1	55 154.6	55 571.6	55 990.3	56 410.4	56 832.2
27	57 255.5	57 680.4	58 106.9	58 534.9	58 964.6	59 395.7	59 828.5	60 262.8	60 698.7	61 136.2
28	61 575.2	62 015.8	62 458.0	62 901.8	63 347.1	63 794.0	63 242.4	64.692.5	65 144.1	65 597.2
29	66 052.0	66 508.3	66 966.2	67 425.7	67 886.7	68 349.3	68 813.5	69 279.2	69 746.5	70 215.4
30	70 685.8	71 157.9	71 631.5	72 106.6	72 583.4	73 061.7	73 541.5	74 023.0	74 506.0	74 990.6
31	75 476.8	75 964.5	76 453.8	76 944.7	77 437.1	77 931.1	78 426.7	78 923.9	79 422.6	79 922.9
32	80 424.8	80 928.2	81 433.2	81 939.8	82 448.0	82 957.7	83 469.0	83 981.8	84 496.3	85 012.3
33	85 529.9	86 049.0	86 569.7	87 092.0	87 615.9	88 141.3	88 668.3	89 196.9	89 727.0	90 258.7
34	90 792.0	91 326.9	91 863.3	92 401.3	92 940.9	93 482.0	94 024.7	94 569.0	95 114.9	95 662.3
35	96 211.3	96 761.8	97 314.0	97 867.7	98 423.0	98 979.8	99 538.2	100 098.	100 660.	101 223.
36	101 788.	102 354.	102 922.	103 491.	104 062.	104 635.	105 209.	105 784.	106 362.	106 941.
37	107 521.	108 103.	108 687.	109 272.	109 858.	110 447.	111 036.	111 628.	112 221.	112 815.
38	113 411.	114 009.	114 608.	115 209,	115 812.	116 416.	117 021.	117 628.	118 237.	118 847.
39	119 459.	120 072.	120 687.	121 304.	121 922.	122 542.	123 163.	123 786.	124 410.	125 036.

AREAS OF CIRCLES IN SQUARE UNITS.

DIAMETER OF WIRE.

	0	1	2	3	4	5	6	7	8	9
40	125 664	126 293	126 923	127 556	128 190	128 825	129 462	130 100	130 741	131 382
41	132 025	132 670	133 317	133 965	134 614	135 265	135 918	136 572	137 228	137 885
42	138 544	139 205	139 867	140 531	141 196	141 863	142 531	143 201	143 872	144 545
43	145 220	145 896	146 574	147 254	147 934	148 617	149 301	149 987	150 674	151 363
44	152 053	152 745	153 439	154 134	154 830	155 528	156 228	156 930	157 633	158 337
45	159 043	159 751	160 460	161 171	161 883	162 597	163 313	164 030	164 748	165 468
46	166 190	166 914	167 639	168 365	169 093	169 823	170 554	171 287	172 021	172 757
47	173 494	174 234	174 974	175 716	176 460	177 205	177 952	178 701	179 451	180 203
48	180 956	181 711	182 467	183 225	183 984	184 745	185 508	186 272	187 038	187 805
49	188 574	189 345	190 117	190 890	191 665	192 442	193 221	194 000	194 782	195 565
50	196 350	197 136	197 923	198 713	199 504	200 296	201 090	201 886	202 683	203 482
51	204 282	205 084	205 887	206 692	207 499	208 307	209 117	209 928	210 741	211 556
52	212 372	213 189	214 008	214 829	215 651	216 475	217 301	218 128	218 956	219 787
53	220 618	221 452	222 287	223 123	223 961	224 801	225 642	226 484	227 329	228 175
54	229 022	229 871	230 722	231 574	232 428	233 283	234 140	234 998	235 858	236 720
55	237 583	238 448	239 314	240 182	241 051	241 922	242 795	243 669	244 545	245 422
56	246 301	247 181	248 063	248 947	249 832	250 719	251 607	252 497	253 388	254 281
57	255 176	256 072	256 970	257 869	258 770	259 672	260 576	261 482	262 389	263 298
58	264 208	265 120	266 033	266 948	267 865	268 783	269 703	270 624	271 547	272 471
59	273 397	274 325	275 254	276 184	277 117	278 051	278 986	279 923	280 862	281 802

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AREAS OF CIRCLES IN SQUARE UNITS.

DIAMETER OF WIRE.

	0	1	2	3	4	5	6	7	8	9
60	282 743	283 687	284 631	285 573	286 526	287 475	288 426	289 379	290 333	291 289
61	292 247	293 206	294 166	295 128	296 092	297 057	298 024	298 992	299 962	300 934
62	301 907	302 882	303 858	304 836	305 815	306 796	307 779	308 763	309 748	310 736
63	311 725	312 715	313 707	314 700	315 696	316 692	317 690	318 690	319 692	320 695
64	321 699	322 705	323 713	324 722	325 733	326 745	327 759	328 775	329 792	330 810
65	331 831	332 853	333 876	334 901	335 927	336 955	337 985	339 016	340 049	341 084
66	342 119	343 157	344 196	345 237	346 279	347 323	348 368	349 415	350 464	351 514
67	352 565	353 618	354 673	355 730	356 788	357 847	358 908	359 971	361 035	362 101
68	363 168	364 237	365 308	366 380	367 453	368 528	369 605	370 684	371 764	372 845
69	373 928	375 013	376 099	377 187	378 276	379 367	380 459	381 554	382 649	383 746
70	384 845	385 945	387 047	388 151	389 256	390 363	391 471	392 580	393 692	394 805
71	395 919	397 035	398 153	399 272	400 393	401 515	402 639	403 765	404 892	406 020
72	407 150	408 282	409 416	410 550	411 687	412 825	413 965	415 106	416 248	417 393
73	418 539	419 686	420 835	421 986	423 138	424 292	425 447	426 604	427 762	428 922
74	430 084	431 247	432 412	433 578	434 746	435 916	437 087	438 259	439 433	440 609
75	441 786	442 965	444 146	445 328	446 511	447 697	448 883	450 072	451 262	452 453
76	453 646	454 841	456 037	457 234	458 434	459 635	460 837	462 041	463 247	464 454
77	465 663	466 873	468 085	469 298	470 513	471 730	472 948	474 168	475 389	476 612
78	477 836	479 062	480 290	481 519	482 750	483 982	485 216	486 451	487 688	488 927
79	490 167	491 409	492 652	493 897	495 143	496 391	497 641	498 892	500 145	501 399

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AREA OF CIRCLES IN SQUARE UNITS.

DIAMETER OF WIRE.

	0	1	2	3	4	5	6	7	8	9
80	502 655	503 912	505 171	506 432	507 694	508 958	510 223	511 490	512 758	514 028
81	515 300	516 573	517 848	519 124	520 402	521 681	522 962	524 245	525 529	526 814
82	528 102	529 391	530 681	531 973	533 267	534 562	535 858	537 157	538 456	539 758
83	541 061	542 365	543 671	544 979	546 288	547 599	548 912	550 226	551 541	552 858
84	554 177	555 497	556 819	558 142	559 467	560 794	562 122	563 452	564 783	566 116
85	567 450	568 786	570 124	571 463	572 803	574 146	575 490	576 835	578 182	579 530
86	580 880	582 232	583 585	584 940	586 297	587 655	589 014	590 375	591 738	593 102
87	594 468	595 835	597 204	598 575	599 947	601 320	602 696	604 073	605 451	606 831
88	608 212	609 595	610 980	612 366	613 754	615 143	616 534	617 927	619 321	620 717
89	622 114	623 513	624 913	626 315	627 718	629 124	630 530	631 938	633 348	634 760
90	636 173	637 587	639 003	640 421	641 840	643 261	644 683	646 107	647 533	648 960
91	650 388	651 818	653 250	654 684	656 118	657 555	658 993	660 433	661 874	663 317
92	664 761	666 207	667 654	669 103	670 554	672 006	673 460	674 915	676 372	677 831
93	679 291	680 753	682 216	683 680	685 147	686 615	688 084	689 555	691 028	692 502
94	693 978	695 455	696 934	698 415	699 897	701 380	702 865	704 352	705 840	707 330
95	708 822	710 315	711 810	713 306	714 803	716 303	717 804	719 306	720 810	722 316
96	723 823	725 332	726 842	728 354	729 867	731 382	732 899	734 417	735 937	737 458
97	738 981	740 506	742 032	743 559	745 088	746 619	748 151	749 685	751 221	752 758
98	754 296	755 837	757 378	758 922	760 466	762 013	763 561	765 111	766 662	768 214
99	769 769	771 325	772 882	774 441	776 002	777 564	779 128	780 693	782 260	783 828

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WIRE GAUGES.

Brown and Sharpe Gauge.

This is abbreviated B. & S. Nearly all copper wire, bare and insulated, is ordered, manufactured, and carried in stock in accordance with this gauge. This might be called the copper wire gauge.

New British Standard Gauge.

This is abbreviated N. B. S. G. The following names are also used:

English Legal Standard Wire Gauge.
Imperial Wire Gauge.

This gauge is the legal standard for Great Britain and is used for all kinds of wire. Its use in this country is very limited.

Roebling Gauge.

This is the same as the Washburn and Moen Gauge, or the American Steel and Wire Gauge, except the diameters in most cases are given to the nearest mil.

This gauge is so generally used for steel wire that it is sometimes called the Steel Wire Gauge or the Market Wire Gauge.

Birmingham Wire Gauge.

This is abbreviated B. W. G. It is the same as Stubs' Iron Wire Gauge, but entirely different from Stubs' Steel Wire Gauge. Galvanized Telegraph and Telephone Wire, both bare and insulated, and Galvanized Armor Wire are usually designated by this gauge. Its use is not very extensive and is becoming less.

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WIRE GAUGES IN MILS.

Numbers.	Roebling.	Brown & Sharpe.	Birmingham.	New British Standard.
0 000 000	.....	.....	.....	500.
000 000	460.	.....	.....	464.
00 000	430.	.....	.....	432.
0 000	393.	460.	454.	400.
000	362.	410.	425.	372.
00	331.	365.	380.	348.
0	307.	325.	340.	324.
1	283.	289.	300.	300.
2	263.	258.	284.	276.
3	244.	229.	259.	252.
4	225.	204.	238.	232.
5	207.	182.	220.	212.
6	192.	162.	203.	192.
7	177.	144.	180.	176.
8	162.	128.	165.	160.
9	148.	114.	148.	144.
10	135.	102.	134.	128.
11	120.	91.	120.	116.
12	105.	81.	109.	104.
13	92.	72.	95.	92.
14	80.	64.	83.	80.
15	72.	57.	72.	72.
16	63.	51.	65.	64.
17	54.	45.	58.	56.
18	47.	40.	49.	48.
19	41.	36.	42.	40.
20	35.	32.	35.	36.
21	32.	28.5	32.	32.
22	28.	25.3	28.	28.
23	25.	22.6	25.	24.
24	23.	20.1	22.	22.
25	20.	17.9	20.	20.
26	18.	15.9	18.	18.
27	17.	14.2	16.	16.4
28	16.	12.6	14.	14.8
29	15.	11.3	13.	13.6
30	14.	10.	12.	12.4
31	13.5	8.9	10.	11.6
32	13.	8.	9.	10.8
33	11.	7.1	8.	10.0
34	10.	6.3	7.	9 2
35	9.5	5.6	5.	8.4
36	9.	5.0	4.	7.6
37	8.5	4.5	.....	6.8
38	8.0	4.0	.....	6.0
39	7.5	3.5	.....	5.2
40	7.0	3.1	.....	4 8

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AREA IN SQUARE MILS.

Numbers.	Roebling.	Brown & Sharpe.	Birmingham.	New British Standard.
0 000 000	.....	.....	.....	196 350.
000 000	166 190.	.....	.....	169 093.
00 000	145 220.	.....	....	146 574.
0 000	121 304.	166 190.	161 883.	125 664.
000	102 922.	131 795.	141 863.	108 687.
00	86 049.0	104 518.	113 411.	95 114.9
0	74 023.0	82 887.0	90 792.0	82 448.0
1	62 901.8	65 732.1	70 685.8	70 685.8
2	54 325.2	52 127.9	63 347.1	59 828.5
3	46 759.5	41 339.3	52 685.3	49 875.9
4	39 760.8	32 783.5	44 488.1	42 273.3
5	33 653.5	25 998.6	38 013.3	35 298.9
6	28 952.9	20 617.8	32 365.5	28 952.9
7	24 605.7	16 350.7	25 446.9	24 328.5
8	20 612.0	12 966.7	21 382.5	20 106.2
9	17 203.4	10 283.1	17 203.4	16 286.0
10	14 313.9	8 154.79	14 102.6	12 868.0
11	11 309.7	6 467.05	11 309.7	10 568.3
12	8 659.01	5 128.61	9 331.32	8 494.87
13	6 647.61	4 067.17	7 088.22	6 647.61
14	5 026.55	3 225.41	5 410.61	5 026.55
15	4 071.50	2 557.87	4 071.50	4 071.50
16	3 117.25	2 028.48	3 318.31	3 216.99
17	2 290.22	1 608.66	2 642.08	2 463.01
18	1 734.94	1 275.72	1 885.74	1 809.56
19	1 320.25	1 011.69	1 385.44	1 256.64
20	962.113	802.308	962.113	1 017.88
21	804.248	636.262	804.248	804.248
22	615.752	504.579	615.752	615.752
23	490.874	400.149	490.874	452.389
24	415.476	317.333	380.133	380.133
25	314.159	251.656	314.159	314.159
26	254.469	199.573	254.469	254.469
27	226.980	158.268	201.062	211.241
28	201.062	125.512	153.938	172.064
29	176.715	99.531 9	132.732	145.267
30	153.938	78.935 7	113.097	120.763
31	143.139	62.598 7	78.539 8	105.683
32	132.732	49.643 1	63.617 3	91.608 8
33	95.033 2	39.368 7	50.265 5	78.539 8
34	78.539 8	31.220 8	38.484 5	66.476 1
35	70.882 2	24.759 2	19.635 0	55.417 7
36	63.617 3	19.635 0	12.566 4	45.364 6
37	56.745 0	15.571 2	.....	36.316 8
38	50.265 5	12.348 6	.....	28.274 3
39	44.178 6	9.792 82	.....	21.237 2
40	38.484 5	7.766 07	.....	18.095 6

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CENTIGRADE TO FAHRENHEIT.

	0	1	2	3	4	5	6	7	8	9
—4	40.0	41 8	43.6	45.4	47.2	49.0	50.8	52.6	54.4	56.2
—3	22.0	23.8	25.6	27.4	29.2	31.0	32.8	34.6	36.4	38.2
—2	4.0	5.8	7.6	9.4	11.2	13.0	14.8	16.6	18.4	20.2
—1	14.0	12.2	10.4	8.6	6.8	5.0	3.2	1.4	.4	2.2
—0	32.0	30.2	28.4	26.6	24.8	23.0	21.2	19.4	17.6	15.8
0	32.0	33.8	35.6	37.4	39.2	41.0	42.8	44.6	46.4	48.2
1	50.0	51.8	53.6	55.4	57.2	59.0	60.8	62.6	64.4	66.2
2	68.0	69.8	71.6	73.4	75.2	77.0	78.8	80.6	82.4	84.2
3	86.0	87.8	89.6	91.4	93.2	95.0	96.8	98.6	100.4	102.2
4	104.0	105.8	107.6	109.4	111.2	113.0	114.8	116.6	118.4	120.2
5	122.0	123.8	125.6	127.4	129.2	131.0	132.8	134.6	136.4	138 2
6	140.0	141.8	143.6	145.4	147.2	149.0	150.8	152.6	154.4	156.2
7	158.0	159.8	161.6	163.4	165.2	167.0	168.8	170.6	172.4	174.2
8	176.0	177.8	179.6	181.4	183.2	185.0	186.8	188.6	190.4	192.2
9	194.0	195.8	197.6	199.4	201.2	203.0	204.8	206.6	208.4	210.2

Add or Subtract for Tenths of a Degree.

0		.18	.36	.54	.72	.90	1.08	1.26	1.44	1.62

The results are minus above the line.

FAHRENHEIT TO CENTIGRADE.

	0	1	2	3	4	5	6	7	8	9
0	17.8	17.2	16.7	16.1	15.6	15.0	14.4	13.9	13.3	12.8
1	12.2	11.7	11.1	10.6	10.0	9.4	8.9	8.3	7.8	7.2
2	6.7	6.1	5.6	5.0	4.4	3.9	3.3	2.8	2.2	1.7
3	1.1	.6	0.0	.6	1.1	1.7	2.2	2.8	3.3	3.9
4	4.4	5.0	5.6	6.1	6.7	7.2	7.8	8.3	8.9	9.4
5	10.0	10.6	11.1	11.7	12.2	12.8	13.3	13.9	14.4	15.0
6	15.6	16.1	16.7	17.2	17.8	18.3	18.9	19.4	20.0	20.6
7	21.1	21.7	22.2	22.8	23.3	23.9	24.4	25.0	25.6	26.1
8	26.7	27.2	27.8	28.3	28.9	29.4	30.0	30.6	31.1	31.7
9	32.2	32.8	33.3	33.9	34.4	35.0	35.6	36.1	36.7	37.2
10	37.8	38.3	38.9	39.4	40.0	40.6	41.1	41.7	42.2	42.8
11	43.3	43.9	44.4	45.0	45.6	46.1	46.7	47.2	47.8	48.3
12	48.9	49.4	50.0	50.6	51.1	51.7	52.2	52.8	53.3	53.9
13	54.4	55.0	55.6	56.1	56.7	57.2	57.8	58.3	58.9	59.4
14	60.0	60.6	61.1	61.7	62.2	62.8	63.3	63.9	64.4	65.0
15	65.6	66.1	66.7	67.2	67.8	68.3	68.9	69.4	70.0	70.6
16	71.1	71.7	72.2	72.8	73.3	73.9	74.4	75.0	75.6	76.1
17	76.7	77 2	77.8	78.3	78.9	79.4	80.0	80.6	81.1	81.7
18	82 2	82.8	83.3	83.9	84.4	85.0	85.6	86.1	86.7	87.2
19	87.8	88.3	88.9	89.4	90.0	90.6	91.1	91.7	92.2	92.8

The results are minus above the line.

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DECIMALS AND MILLIMETER EQUIVALENTS OF PARTS OF AN INCH.

16ths.	32ds.	64ths.	Mils.	Millimeters.	16ths.	32ds.	64ths.	Mils.	Millimeters.
		1	15.625	.397			33	515.625	13.10
	1	2	31.25	.794		17	34	531.25	13.49
		3	46.875	1.191			35	546.875	13.89
1	2	4	62.5	1.588	9	18	36	562.5	14.29
		5	78.125	1.984			37	578.125	14.68
	3	6	93.75	2.381		19	38	593.75	15.08
		7	109.375	2.778			39	609.375	15.48
2	4	8	125.	3.175	10	20	40	625.	15.88
		9	140.625	3.572			41	640.625	16.27
	5	10	156.25	3.969		21	42	656.25	16.67
		11	171.875	4.366			43	671.875	17.07
3	6	12	187.5	4.763	11	22	44	687.5	17.46
		13	203.125	5.159			45	703.125	17.86
	7	14	218.75	5.556		23	46	718.75	18.26
		15	234.375	5.953			47	734.375	18.65
4	8	16	250.	6.350	12	24	48	750.	19.05
		17	265.625	6.747			49	765.625	19.45
	9	18	281.25	7.144		25	50	781.25	19.84
		19	296.875	7.541			51	796.875	20.24
5	10	20	312.5	7.938	13	26	52	812.5	20.64
		21	328.125	8.334			53	828.125	21.03
	11	22	343.75	8.731		27	54	843.75	21.43
		23	359.375	9.128			55	859.375	21.83
6	12	24	375.	9.525	14	28	56	875.	22.23
		25	390.625	9.922			57	890.625	22.62
	13	26	406.25	10.32		29	58	906.25	23.02
		27	421.875	10.72			59	921.875	23.42
7	14	28	437.5	11.11	15	30	60	937.5	23.81
		29	453.125	11.51			61	953.125	24.21
	15	30	468.75	11.91		31	62	968.75	24.61
		31	484.375	12.30			63	984.375	25.00
8	16	32	500.	12.70	16	32	64	1000.	25.40

INCHES AND FRACTIONS OF AN INCH IN DECIMALS OF A FOOT.

Ins.	0	⅛	¼	⅜	½	⅝	¾	⅞
0	0	.0104	.0208	.0313	.0417	.0521	.0625	.0729
1	.0833	.0938	.1042	.1146	.1250	.1354	.1458	.1563
2	.1667	.1771	.1875	.1979	.2083	.2188	.2292	.2396
3	.2500	.2604	.2708	.2813	.2917	.3021	.3125	.3229
4	.3333	.3438	.3542	.3646	.3750	.3854	.3958	.4063
5	.4167	.4271	.4375	.4479	.4583	.4688	.4792	.4896
6	.5000	.5104	.5208	.5313	.5417	.5521	.5625	.5729
7	.5833	.5938	.6042	.6146	.6250	.6354	.6458	.6563
8	.6667	.6771	.6875	.6979	.7083	.7188	.7292	.7396
9	.7500	.7604	.7708	.7813	.7917	.8021	.8125	.8229
10	.8333	.8438	.8542	.8646	.8750	.8854	.8958	.9063
11	.9167	.9271	.9375	.9479	.9583	.9688	.9792	.9896

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COPPER WIRE.

THE Bureau of Standards in their Circular No. 31, issued January 1, 1914, gives the values adopted by the International Electrotechnical Commission on September 5, 1913, as follows:

"(1) At a temperature of 20° C, the resistance of a wire of standard annealed copper, one meter in length and of a uniform section of one square millimeter, is $\frac{1}{58}$ ohm or 0.017241 ... ohm.

(2) At a temperature of 20° C, the density of standard annealed copper is 8.89 grams per cubic centimeter.

(3) At a temperature of 20° C, the 'constant mass' temperature coefficient of resistance of standard annealed copper, measured between two potential points rigidly fixed to the wire is 0.00393 or $\frac{1}{254.45}$ per degree centigrade.

(4) As a consequence, it follows from (1) and (2) that, at a temperature of 20° C, the resistance of a wire of standard annealed copper of uniform section one meter in length and weighing one gram is $\left[(\frac{1}{58}) \times 8.89 \right]$ or 0.15328 ... ohm.

(5) The coefficient of linear expansion of annealed copper is .000017 per degree centigrade."

Resistance of Copper Wire at 20° C based on Section or Diameter.

At a given temperature, the resistance of a wire

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of uniform section varies directly as the length and inversely as the section

$$R = \frac{k\,l}{s} \qquad\qquad k = \frac{R\,s}{l}$$

R = resistance in ohms.
s = section.
k = a constant depending on the units of length and section. It is the resistance in ohms of unit length of unit section.

The resistance of a meter circular millimeter is found by substituting in the first formula.

$$\text{Meter circular millimeter} = \frac{1/68}{.7854} \text{ ohms.}$$

Resistance.

LENGTH.	SECTION.	OHMS.
Meter	square millimeter	.017 241 379 31
Foot	square millimeter	.005 255 182 924
Mile	square millimeter	27.747 365 84
Meter	circular millimeter	.021 952 405 95
Foot	circular millimeter	.006 691 106 716
Mile	circular millimeter	35.329 043 47
Meter	square mil	26.724 084 48
Foot	square mil	8.145 517 243
Mile	square mil	43 008.331 04
Meter	circular mil	34.026 161 16
Foot	circular mil	10.371 194 66
Mile	circular mil	54 759.9078 4
Kilometer	square inch	.026 724 084 48
1000 feet	square inch	.008 145 517 243
Mile	square inch	.043 008 331 04

The foot values = meter values × .304 800 609 6.
The mile values = meter values × 1609.347 219.
Square millimeter = 1549.9969 square mils.

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Resistance of Copper Wire at 20° C based on Weight.

At a given temperature, the resistance of a wire of uniform section varies directly as the square of the length, and inversely as the weight.

$$R = \frac{k\,l^2}{w} \qquad k = \frac{R\,w}{l^2}$$

k = the resistance in ohms of unit length of unit weight.

The resistance of a foot gram is found by substituting in the first formula.

Foot gram = .15328 ohms × $.3048^2$.
Mile gram = .15328 ohms × 1609.34^2.

Resistance.

LENGTH	WEIGHT.	OHMS.
Meter	gram	.153 275 862 1
Foot	gram	.014 239 850 51
Mile	gram	396 984.248 5
Kilometer	pound	337.915 389 9
1000 feet	pound	31.393 492 57
Mile	pound	875.200 343 2

The pound units = the gram units × .002 204 622 341.

Weight of Annealed Copper Wire at 20° C.

At a given temperature the weight of a wire of uniform section varies directly as the length and section.

$$w = k\,l\,s$$

k is the weight of a unit length of unit section in the units of weight used. For meter square millimeter grams k = 8.89, and for meter circular millimeter pounds k = .015 393.

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The following table gives the weight for various unit lengths and sections at 20° C:

Weight.

LENGTH.	SECTION.	GRAMS.	POUNDS.
Meter	square millimeter	8.89	.019 599 092 61
Foot	square millimeter	2.709 677 419	.005 973 815 375
Mile	square millimeter	14 307.096 78	31.541 745 20
Meter	circular millimeter	6.982 189 673	.015 393 091 34
Foot	circular millimeter	2.128 175 669	.004 691 823 625
Mile	circular millimeter	11 236.767 53	24.772 828 74
Kilometer	square mil	5.735 495 342	.012 644 601 17
1000 feet	square mil	1.748 182 477	.003 854 082 145
Mile	square mil	9.230 403 478	.020 349 553 72
Kilometer	circular mil	4.504 647 508	.009 931 046 534
1000 feet	circular mil	1.373 019 306	.003 026 989 037
Mile	circular mil	7.249 541 940	.015 982 502 12
Kilometer	square inch	5 735 495.342	12 644.601 17
1000 feet	square inch	1 748 182.477	3 854.082 145
Mile	square inch	9 230 403.478	20 349.553 72

In making these and the following calculations, the factors and results were taken to the nearest tenth place of significant figures. In some of the formulas the number is indicated, but the entire ten significant figures are not given. In ordinary calculations the nearest four or five significant figures are sufficient.

The three tables at 20° C for resistance by section, resistance by weight, and weight, may be computed for any other temperature by means of the constant mass temperature coefficient of .003 93 and the coefficient of linear expansion .000 017 per degree centigrade.

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Constants for Annealed Copper at 0° C.

A meter square millimeter of annealed copper at 20° has the following values at 0° C.

Resistance = 1/58 ohm × .9214 or .015 886 206 90 ohms.
Weight = 8.89 grams.
Length = .999 66 meters.
Section = .999 66² millimeters.
.921 4 = 1 — (.003 93 × 20).
.999 66 = 1 — (.000 017 × 20).

The resistance of a meter square millimeter is—

$$\frac{.015\,886 \times .999\,66^2}{.999\,66} \text{ or } .015\,880\,805\,59 \text{ ohms.}$$

The density is 8.89 ÷ .999 66² or 8.899 073 969

The resistance of a meter gram at 0° is the product of—

.015 880 7 and 8.899 073 or .141 324 463 6 ohms.

Temperature coefficient from 0° is—

$$\frac{.00\,393}{.9214} \text{ or } .004\,265\,25$$

The following table gives the resistances of the meter square millimeter and the meter gram at 20° and 0° in ohms and a comparison of other properties of copper at these two temperatures:

Summary.

	20°	0°
Meter square millimeter at 20°	.017 241 379 31	.015 886 206 90
Meter square millimeter at 0°		.015 880 805 59
Meter gram at 20°	.153 275 862 1	.141 228 379 3
Meter gram at 0°		.141 324 463 6
Temperature coefficient	.003 93	.004 265
Density	8.89	8.90
Linear expansion	.000 017	.000 017

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Conductivity.

The conductivity of copper at 20° C is the result obtained by dividing the resistance of a standard at that temperature, of the same length and section, or the same length and weight, as the sample under test, by the resistance of the sample at 20° C. The conductivity of copper, where it is not 100%, varies with the temperature. When no temperature is specified, 20° is always understood. The resistance at 20° of a wire with 90% conductivity is found by dividing the standard resistance by .90.

Temperature Coefficients.

The resistance of copper varies with the temperature.

The meter square millimeter of copper at 20° C has a resistance of 1/58 ohm. This same piece of copper at 0° C will have a less resistance, represented by the expression—

$$\frac{1}{58}\text{ ohm} \times \left[1. - (.003\,93 \times 20)\right]$$

The resistance of a meter gram of copper at 20° C multiplied by the same factor gives the resistance of the same piece of copper at 0° C. The length and section of copper at 0° are less than the length and section at 20° C, but the mass is the same. The temperature coefficient of constant mass is .003 93 multiplied by the conductivity. For 90% conductivity the temperature coefficient is .003 537.

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The resistance at 0° C of a meter square millimeter of copper at 0° is another matter. We must not only use the temperature coefficient .00393 but we must bring in the coefficient of linear expansion .000 017, as is done on page 61. There is a factor per degree connecting the resistance of a meter square millimeter of copper at 20° and the resistance of the same volume, but not the same mass at 0° C. This factor may be called the temperature coefficient of constant volume.

The resistance at 0° C of a meter gram of copper at 0° C takes account not only of the temperature coefficient .003 93, but also of the coefficient of linear expansion .000 017.

A meter gram of copper at 0° C has the same mass and the same length, but a different volume, than a meter gram of copper at 20°.

The factor per degree connecting the resistance of a meter gram at 20° C and a meter gram at 0° may be called the temperature coefficient of constant mass and length.

The following method may be used to get the resistance at any temperature t°, and at any conductivity c of copper wire, the resistance of which at 20° C and 100% conductivity is known.

a = the resistance of given length and given section at 20° C, 100% conductivity.

b = the resistance of given length and given weight at 20° C, 100% conductivity.

c = the conductivity expressed as a decimal.

d = the temperature coefficient $.003\,93 \times (t° - 20°)$

$$e = 1 + \left[.000\,017 \times (t° - 20°) \right]$$

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Temperature Coefficient of Constant Mass.

When length and section are defined at 20° C, the resistance of that piece of copper at any other temperature t°, and conductivity c, is defined by the expression:

$$R = \frac{a}{c}(1 + c\,d)$$
$$= a\left(\frac{1}{c} + d\right)$$

At 0° C and 95% conductivity,

$c = .95$
$d = -.0786$
$\left(\frac{1}{c} + d\right)$ is .974 032

The resistance of a copper wire of any length and any section, or of any length and any mass, at 20° C and 100% conductivity, multiplied by this factor, gives the resistance of that same piece of wire, having a different length and section, but the same mass at 0° C and 95% conductivity.

Other factors may be worked out for other temperatures and other conductivities, as shown in the following table:

The tables of the properties of copper wire give the resistance per 1000 feet, per mile, or per kilometer, at 20° C for 100% conductivity. These values multiplied by the factors in the following table give the resistance at other temperatures and conductivities of certain lengths at 20° C. 1000 feet No. 10 B. & S. copper wire at 20° C and 100% conductivity has a resistance of .9989 ohms. This resistance multiplied by 1.127 302 gives the resistance of this piece of copper at 39° C for 95% conductivity. It is no longer 1000 feet long and no longer No. 10 B. & S.

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COEFFICIENTS OF CONSTANT MASS.

C°	100%	99%	98%	97%	96%	95%
0	.921 400	.931 501	.941 808	.952 328	.963 067	.974 032
5	.941 050	.951 151	.961 458	.971 978	.982 717	.993 682
6	.944 980	.955 081	.965 388	.975 908	.986 647	.997 612
7	.948 910	.959 011	.969 318	.979 838	.990 577	1.001 542
8	.952 840	.962 941	.973 248	.983 768	.994 507	1.005 472
9	.956 770	.966 871	.977 178	.987 698	.998 437	1.009 402
10	.960 700	.970 801	.981 108	.991 628	1.002 367	1.013 332
11	.964 630	.974 731	.985 038	.995 558	1.006 297	1.017 262
12	.968 560	.978 661	.988 968	.999 488	1.010 227	1.021 192
13	.972 490	.982 591	.992 898	1.003 418	1.014 157	1.025 122
14	.976 420	.986 521	.996 828	1.007 348	1.018 087	1.029 052
15	.980 350	.990 451	1.000 758	1.011 278	1.022 017	1.032 982
16	.984 280	.994 381	1.004 688	1.015 208	1.025 947	1.036 912
17	.988 210	.998 311	1.008 618	1.019 138	1.029 877	1.040 842
18	.992 140	1.002 241	1.012 548	1.023 068	1.033 807	1.044 772
19	.996 070	1.006 171	1.016 478	1.026 998	1.037 737	1.048 702
20	1.000 000	1.010 101	1.020 408	1.030 928	1.041 667	1.052 632
21	1.003 930	1.014 031	1.024 338	1.034 858	1.045 597	1.056 562
22	1.007 860	1.017 961	1.028 268	1.038 788	1.049 527	1.060 492
23	1.011 790	1.021 891	1.032 198	1.042 718	1.053 457	1.064 422
24	1.015 720	1.025 821	1.036 128	1.034 858	1.057 387	1.068 352
25	1.019 650	1.029 751	1.040 058	1.050 578	1.016 317	1.072 282
26	1.023 580	1.033 681	1.043 988	1.054 508	1.065 247	1.076 212
27	1.027 510	1.037 611	1.047 918	1.058 438	1.069 177	1.080 142
28	1.031 440	1.041 541	1.051 848	1.062 368	1.073 107	1.084 072
29	1.035 370	1.045 471	1.055 778	1.066 298	1.077 037	1.088 002
30	1.039 300	1.049 401	1.059 708	1.070 228	1.080 967	1.091 932
31	1.043 230	1.053 331	1.063 638	1.074 158	1.084 897	1.095 862
32	1.047 160	1.057 261	1.067 568	1.078 088	1.088 827	1.099 792
33	1.051 090	1.061 191	1.071 498	1.082 018	1.092 757	1.103 722
34	1.055 020	1.065 121	1.075 428	1.085 948	1.096 687	1.107 652
35	1.058 950	1.069 051	1.079 358	1.089 878	1.100 617	1.111 582
36	1.062 880	1.072 981	1.083 288	1.093 808	1.104 547	1.115 512
37	1.066 810	1.076 911	1.087 218	1.097 738	1.108 477	1.119 442
38	1.070 740	1.080 841	1.091 148	1.101 668	1.112 407	1.123 372
39	1.074 670	1.084 771	1.095 078	1.105 598	1.116 337	1.127 302
40	1.078 600	1.088 701	1.099 008	1.109 528	1.120 267	1.131 232
45	1.098 250	1.108 351	1.118 658	1.129 178	1.139 917	1.150 882
50	1.117 900	1.128 001	1.138 308	1.148 828	1.159 567	1.170 532
55	1.137 550	1.147 651	1.157 958	1.168 478	1.179 217	1.190 182
60	1.157 200	1.167 301	1.177 608	1.188 128	1.198 867	1.209 832
65	1.176 850	1.186 951	1.197 258	1.207 778	1.218 517	1.229 482
70	1.196 500	1.206 601	1.216 908	1.227 428	1.238 167	1.249 132
75	1.216 150	1.226 251	1.236 558	1.247 078	1.257 817	1.268 782
60° F	.982 533	.992 634	1.002 941	1.013 461	1.024 200	1.035 165
75° F	1.015 283	1.025 384	1.035 691	1.046 211	1.056 950	1.067 915

Values of $\left(\frac{1}{c} + d\right)$

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Temperature Coefficient of Constant Volume.

For resistance defined by length and section we have the following expression for temperature t° and conductivity c:

$$R = \frac{a\,e^2}{c\,e}(1 + cd)$$

$$= a\,e\left(\frac{1}{c} + d\right)$$

At 0° C and 95% conductivity,

$e = .999\,66$

$c = .95$

$d = -.0786$

$e\left(\frac{1}{c} + d\right) = .973\,700$

The resistance of a copper wire of any length and any section at 20° C and 100% conductivity, multiplied by this factor, gives the resistance of the same length of wire with the same section at 0° C and with 95% conductivity. Other factors may be worked out for other temperatures and other conductivities, as shown in the following table:

A table of the electrical resistance of copper wire at any temperature and conductivity may be derived from such a table at 20° C by multiplying by the proper factor. For 25° C and 100% conductivity the factor is 1.019 737. The resistance in ohms per 1000 feet or per mile at 20° C multiplied by this factor gives the ohms per 1000 feet or per mile at 25° C. A table of the resistance of hard drawn copper wire at 15° C and 97% conductivity may be derived from the table given on page 76 by multiplying the resistances by 1.011 192.

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COEFFICIENTS OF CONSTANT VOLUME.

C°	100%	99%	98%	97%	96%	95%
0	.921 087	.931 184	.941 488	.952 004	.962 739	.973 700
5	.940 810	.950 908	.961 213	.971 730	.982 466	.993 428
6	.944 755	.954 854	.965 158	.975 676	.986 412	.997 374
7	.948 700	.958 799	.969 104	.979 621	.990 358	1.001 320
8	.952 646	.962 745	.973 050	.983 567	.994 304	1.005 266
9	.956 591	.966 690	.976 995	.987 513	.998 250	1.009 213
10	.960 537	.970 636	.980 941	.991 459	1.002 196	1.013 159
11	.964 482	.974 582	.984 887	.995 406	1.006 143	1.017 106
12	.968 428	.978 528	.988 834	.999 352	1.010 089	1.021 053
13	.972 374	.982 474	.992 780	1.003 298	1.014 036	1.025 000
14	.976 320	.986 420	.996 726	1.007 245	1.017 983	1.028 947
15	.980 267	.990 367	1.000 673	1.011 192	1.021 930	1.032 894
16	.984 213	.994 313	1.004 620	1.015 139	1.025 877	1.036 841
17	.988 160	.998 260	1.008 567	1.019 086	1.029 824	1.040 788
18	.992 106	1.002 207	1.012 514	1.023 033	1.033 772	1.044 736
19	.996 053	1.006 154	1.016 461	1.026 980	1.037 719	1.048 684
20	1.000 000	1.010 101	1.020 408	1.030 928	1.041 667	1.052 632
21	1.003 947	1.014 048	1.024 356	1.034 875	1.045 614	1.056 580
22	1.007 894	1.017 996	1.028 303	1.038 823	1·049 562	1.060 528
23	1.011 842	1.021 943	1.032 251	1.042 771	1.053 510	1.064 476
24	1.015 789	1.025 891	1.036 199	1.046 719	1.057 459	1.068 424
25	1.019 737	1.029 839	1.040 147	1.050 667	1.061 407	1.072 373
26	1.023 684	1.033 786	1.044 095	1.054 615	1.065 355	1.076 321
27	1.027 632	1.037 734	1.048 043	1.058 564	1.069 304	1.080 270
28	1.031 580	1.041 683	1.051 991	1.062 513	1.073 253	1.084 219
29	1.035 528	1.045 631	1.055 940	1.066 461	1.077 201	1.088 168
30	1.039 477	1.049 579	1.059 888	1.070 409	1.081 150	1.092 117
31	1.043 425	1.053 528	1.063 837	1.074 359	1.085 100	1.096 067
32	1.047 374	1.057 477	1.067 786	1.078 308	1.089 049	1.100 016
33	1.051 322	1.061 426	1.071 735	1.082 257	1.092 998	1.103 966
34	1.055 271	1.065 375	1.075 684	1.086 206	1.096 948	1.107 915
35	1.059 220	1.069 324	1.079 633	1.090 156	1.100 897	1.111 865
36	1.063 169	1.073 273	1.083 583	1.094 105	1.104 847	1.115 815
37	1.067 118	1.077 222	1.087 532	1.098 055	1.108 797	1.119 765
38	1.071 068	1.081 172	1.091 482	1.102 005	1.112 747	1.123 715
39	1.075 017	1.085 121	1.095 432	1.105 955	1.116 697	1.127 666
40	1.078 967	1.089 071	1.099 382	1.109 905	1.120 648	1.131 616
45	1.098 717	1.108 822	1.119 134	1.129 658	1.140 401	1.151 371
50	1.118 470	1.128 576	1.138 889	1.149 414	1.160 158	1.171 129
55	1.138 227	1.148 334	1.158 647	1.169 173	1.179 918	1.190 890
60	1.157 987	1.168 095	1.178 409	1.188 936	1.199 682	1.210 654
65	1.177 750	1.187 859	1.198 174	1.208 702	1.219 449	1.230 422
70	1.197 517	1.207 627	1.217 943	1.228 471	1.239 219	1.250 193
75	1.217 287	1.227 398	1.237 714	1.248 244	1.258 993	1.269 968
60° F	.982 359	.992 559	1.002 866	1.013 385	1.024 123	1.035 087
75° F	1.015 350	1.025 452	1.035 760	1.046 280	1.057 020	1.067 986

Values of $\left(\frac{1}{c} + d\right) e$

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These formulas are true for degrees Fahrenheit, changing the constants as follows:

20° Centigrade = 68° Fahrenheit
.003 93 ÷ 1.8 = .002 183
.000 017 ÷ 1.8 = .000 009 44

A given length and section of copper 100% conductivity has the following resistance from the formula $a\ e\left(\frac{1}{c} + d\right)$

At 21° = a × 1.003 947
At 20° = a × 1.000 000
Difference = a × .003 947

The following table gives the difference in factors for different conductivities at different temperatures.

From	100%	95%	90%
40° to 41°	.003 950	.003 951	.003 952
20° to 21°	.003 947	.003 948	.003 949
0° to 1°	.003 944	.003 945	.003 946

The difference in factors for any given length and section of copper wire is practically uniform. We will take as this difference .003947. The resistance of a copper wire of any length and any section at 20° and 100% conductivity multiplied by this factor gives the difference of resistance of a copper wire of the same length and section for each degree centigrade, independent of the temperature or of the conductivity of the sample. The factor for degrees Fahrenheit is .003 947 ÷ 1.8 or .002 192 8

The addition per degree is—

	Centigrade.	Fahrenheit.
Meter square millimeter	.000 068 1	.000 0378
Foot circular mil	.040 9	.022 722
Mile square inch	.000 170	.000 094

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In order to get the conductivity of a copper wire whose length, diameter, and resistance are known at t°, the resistance of the sample at that temperature must be found for unit length and unit diameter. By adding the constant difference, whose value will depend on the units used, the resistance of unit length and unit diameter may be found at 20° C or 68° F, and dividing this into the corresponding standard resistance gives the conductivity.

When the units are feet and mils and the temperature is expressed in degrees centigrade, the formula is—

$$\text{Conductivity} = \frac{10.371\,2}{\frac{R\,d^2}{l} + .040\,9\,(20^\circ - t^\circ)}$$

Temperature Coefficient of Constant Mass and Length.

For resistance defined by length and weight we have the following expression for temperature t° and conductivity c:

$$R = \frac{b}{c}(1 + c\,d) \div e^2$$

$$= \frac{b}{e^2}\left(\frac{1}{c} + d.\right)$$

At 0° C and 90% conductivity

$$\frac{1}{e^2}\left(\frac{1}{c} + d\right) \text{ is } 1.033\,213\,577$$

Other factors may be worked out for other conductivities, and other temperatures as shown in the following table:

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COEFFICIENTS OF CONSTANT MASS AND LENGTH.

C°	100%	99%	98%	97%	96%	95%
0	.922 027	.932 135	.942 449	.952 976	.963 722	.974 694
5	.941 530	.951 636	.961 949	.972 474	.983 218	.994 189
6	.945 430	.955 536	.965 848	.976 373	.987 116	.998 087
7	.949 330	.959 435	.969 747	.980 271	.991 015	1.001 984
8	.953 229	.963 334	.973 645	.984 169	.994 913	1.005 882
9	.957 128	.967 233	.977 544	.988 067	.998 810	1.005 882
10	.961 027	.971 131	.981 442	.991 965	1.002 708	1.013 676
11	.964 925	.975 029	.985 340	.995 863	1.006 605	1.017 573
12	.968 824	.978 927	.989 237	.999 760	1.010 502	1.021 469
13	.972 721	.982 825	.993 135	1.003 657	1.014 398	1.025 366
14	.976 619	.986 722	.997 032	1.007 553	1.018 294	1.029 262
15	.980 517	.990 619	1.000 928	1.011 450	1.022 190	1.033 157
16	.984 414	.994 516	1.004 825	1.015 346	1.026 086	1.037 053
17	.988 311	.998 413	1.008 721	1.019 242	1.029 982	1.040 948
18	.992 207	1.002 309	1.012 617	1.023 137	1.033 877	1.044 843
19	.996 104	1.006 205	1.016 513	1.027 033	1.037 772	1.048 737
20	1.000 000	1.010 101	1.020 408	1.030 928	1.041 667	1.052 632
21	1.003 896	1.013 997	1.024 303	1.034 823	1.045 561	1.056 526
22	1.007 791	1.017 892	1.028 198	1.038 717	1.049 455	1.060 419
23	1.011 687	1.021 787	1.032 093	1.042 611	1.053 349	1.064 313
24	1.015 582	1.025 682	1.035 987	1.046 506	1.057 243	1.068 206
25	1.019 477	1.029 576	1.039 881	1.050 399	1.061 136	1.072 099
26	1.023 371	1.033 470	1.043 775	1.054 293	1.065 029	1.075 992
27	1.027 265	1.037 364	1.047 669	1.058 186	1.068 922	1.079 885
28	1.031 160	1.041 258	1.051 562	1.062 079	1.072 815	1.083 777
29	1.035 053	1.045 151	1.055 455	1.065 972	1.076 707	1.087 669
30	1.038 947	1.049 044	1.059 348	1.069 864	1.080 599	1.091 560
31	1.042 840	1.052 937	1.063 240	1.073 756	1.084 491	1.095 452
32	1.046 733	1.056 830	1.067 133	1.077 648	1.088 383	1.099 343
33	1.050 626	1.060 722	1.071 025	1.081 540	1.092 274	1.103 234
34	1.054 518	1.064 614	1.074 916	1.085 431	1.096 165	1.107 125
35	1.058 410	1.068 506	1.078 808	1.089 322	1.100 056	1.111 015
36	1.062 302	1.072 398	1.082 699	1.093 213	1.103 946	1.114 905
37	1.066 194	1.076 289	1.086 590	1.097 104	1.107 836	1.118 795
38	1.070 085	1.080 180	1.090 481	1.100 994	1.111 726	1.122 684
39	1.073 976	1.084 071	1.094 371	1.104 884	1.115 616	1.126 574
40	1.077 867	1.087 961	1.098 261	1.108 774	1.118 505	1.130 463
45	1.097 317	1.107 410	1.117 708	1.128 219	1.138 948	1.149 904
50	1.116 761	1.126 851	1.137 148	1.147 657	1.158 385	1.169 339
55	1.136 198	1.146 287	1.156 581	1.167 089	1.177 815	1.188 767
60	1.155 628	1.165 715	1.176 008	1.186 514	1.197 238	1.208 188
65	1.175 051	1.185 137	1.195 428	1.205 932	1.216 654	1.227 603
70	1.194 469	1.204 552	1.214 842	1.225 344	1.236 064	1.247 011
75	1.213 879	1.223 961	1.234 249	1.244 749	1.255 468	1.266 412
60° F	.982 682	.992 784	1.003 093	1.013 614	1.024 355	1.035 321
75° F	1.015 149	1.025 249	1.035 555	1.046 073	1.056 810	1.067 774

Values of $\frac{1}{e^2}\left(\frac{1}{c} + d\right)$

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The resistance of a copper wire of any length and any weight at 20° C and 100% conductivity multiplied by one of these factors gives the resistance of the same length of wire of the same weight at the temperature and conductivity corresponding to the factor.

A given length and weight of copper 100% conductivity has the following resistance, from the formula $\frac{b}{e^2}\left(\frac{1}{c} + d\right)$

At 21° = b × 1.003 896
At 20° = b × 1.000 000
Difference = b × .003 896

The following table gives the difference in factors for different conductivities at different temperatures.

From	100%	95%	90%
40° to 41°	.003 891	.003 889	.003 887
20° to 21°	.003 896	.003 894	.003 892
0° to 1°	.003 901	.003 899	.003 897

The difference in factors for any given length and weight of copper wire is practically uniform. We will take as this difference .003 896. The resistance of a copper wire of any length and weight at 20° C and 100% conductivity multiplied by this factor, gives the difference of resistance of a copper wire of the same length and weight for each degree centigrade, independent of the temperature or of the conductivity of the sample. The factor per degree Fahrenheit is .003 896 ÷ 1.8 or .002 164 4.

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The addition per degree is—

	Centigrade.	Fahrenheit.
Meter gram	.000 597	.000 332
Foot gram	.000 0555	.000 030 8
Mile pound	3.41	1.894 4

In order to get the conductivity of a copper wire whose length, weight, and resistance are known at t°, the resistance of the sample at that temperature must be found for unit length and weight. By adding the constant difference, whose value will depend on the units used, the resistance of unit length and unit weight may be found at 20° C or 68° F., and dividing this into the corresponding standard resistance gives the conductivity.

When the units are meters and grams, and the temperature is expressed in degrees centigrade, the formula is—

$$\text{Conductivity} = \frac{.153\,28}{\frac{R\,w}{l^2} + .000\,597\,(20° - t°)}$$

If the units were feet and grams the constants would change as follows:

.153 28 would be .014 240
.000 597 would be .000 0555.

When the units are feet and grams, and the temperature is expressed in degrees Fahrenheit the formula becomes,

$$\text{Conductivity} = \frac{.014\,240}{\frac{R\,w}{l^2} + .000\,0308\,(68° - t°)}$$

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ADDITIONS
TO OBTAIN RESISTANCE AT 20° C.

C°	Meter gram.	Foot gram.	Mile pound.	Meter square mm.	Foot circular mil.	Mile square inch.
0	.011 940	.001 110 0	68.20	.001 362 0	.818 0	.003 40
5	.008 955	.000 832 5	51.15	.001 021 5	.613 5	.002 55
6	.008 358	.000 777 0	47.74	.000 953 4	.572 6	.002 38
7	.007 761	.000 721 5	44.33	.000 885 3	.531 7	.002 21
8	.007 164	.000 666 0	40.92	.000 817 2	.490 8	.002 04
9	.006 567	.000 610 5	37.51	.000 749 1	.449 9	.001 87
10	.005 970	.000 555 0	34.10	.000 681 0	.409 0	.001 70
11	.005 373	.000 499 5	30.69	.000 612 9	.368 1	.001 53
12	.004 776	.000 444 0	27.28	.000 544 8	.327 2	.001 36
13	.004 179	.000 388 5	23.87	.000 476 7	.286 3	.001 19
14	.003 582	.000 333 0	20.46	.000 408 6	.245 4	.001 02
15	.002 985	.000 277 5	17.05	.000 340 5	.204 5	.000 85
16	.002 388	.000 222 0	13.64	.000 272 4	.163 6	.000 68
17	.001 791	.000 166 5	10.23	.000 204 3	.122 7	.000 51
18	.001 194	.000 111 0	6.82	.000 136 2	.081 8	.000 34
19	.000 597	.000 055 5	3.41	.000 068 1	.040 9	.000 17
20	.000 000	.000 000 0	0.00	.000 000 0	.000 0	.000 00
21	.000 597	.000 055 5	3.41	.000 068 1	.040 9	.000 17
22	.001 194	.000 111 0	6.82	.000 136 2	.081 8	.000 34
23	.001 791	.000 166 5	10.23	.000 204 3	.122 7	.000 51
24	.002 388	.000 222 0	13.64	.000 272 4	.163 6	.000 68
25	.002 985	.000 277 5	17.05	.000 340 5	.204 5	.000 85
26	.003 582	.000 333 0	20.46	.000 408 6	.245 4	.001 02
27	.004 179	.000 388 5	23.87	.000 476 7	.286 3	.001 19
28	.004 776	.000 444 0	27.28	.000 544 8	.327 2	.001 36
29	.005 373	.000 499 5	30.69	.000 612 9	.368 1	.001 53
30	.005 970	.000 555 0	34.10	.000 681 0	.409 0	.001 70
31	.006 567	.000 610 5	37.51	.000 749 1	.449 9	.001 87
32	.007 164	.000 666 0	40.92	.000 817 2	.490 8	.002 04
33	.007 761	.000 721 5	44.33	.000 885 3	.531 7	.002 21
34	.008 358	.000 777 0	47.74	.000 953 4	.572 6	.002 38
35	.008 955	.000 832 5	51.15	.001 021 5	.613 5	.002 55
36	.009 552	.000 888 0	54.56	.001 089 6	.654 4	.002 72
37	.010 149	.000 943 5	57.97	.001 157 7	.695 3	.002 89
38	.010 746	.000 999 0	61.38	.001 225 8	.736 2	.003 06
39	.011 343	.001 054 5	64.79	.001 293 9	.777 1	.003 23
40	.011 940	.001 110 0	68.20	.001 362 0	.818 0	.003 40
45	.014 925	.001 387 5	85.25	.001 702 5	1.022 5	.004 25
50	.017 910	.001 665 0	102.30	.002 043 0	1.227 0	.005 10
55	.020 895	.001 942 5	119.35	.002 383 5	1.431 5	.005 95
60	.023 880	.002 220 0	136.40	.002 724 0	1.636 0	.006 80
65	.026 865	.002 497 5	153.45	.003 064 5	1.840 5	.007 65
70	.029 850	.002 775 0	170.50	.003 405 0	2.045 0	.008 50
75	.032 835	.003 052 5	187.55	.003 745 5	2.249 5	.009 35

Add from 0° to 20°. Subtract from 20° to 75°.

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COPPER WIRE TABLES.

With the exception of No. 0000, which is 460 mils in diameter, and No. 36 which is 5 mils, the diameters of the sizes B. & S. G. are indeterminate. The ratio of the diameter of any one size to that of the next lower size is .890 525 718 5. Using this ratio and deriving the size of each number from the next greater finally gives us 5.000 000 02 mils as the diameter of a No. 36 instead of an even five mils. The ratio is, therefore, slightly too large. The ratio for diameters squared gives the ratio for circulars mils. Multiplying 211 600 by .793 036 055 310 gives the area of No. 000 B. & S. in circular mils, and this result multiplied again by the ratio gives the area of No. 00. In the following formulas d^2 = circular mils, derived in this way.

At 20° C—

$$\text{Ohms per 1000 feet} = \frac{10\,371.2}{d^2}$$

$$\text{Ohms per mile} = \frac{54\,759.9}{d^2}$$

$$\text{Ohms per kilometer} = \frac{34\,026.2}{d^2}$$

Pounds per 1000 feet = .003 027 d^2
Pounds per mile = .015 982 5 d^2
Kilograms per kilometer = .004 504 65 d^2

These constants are given in the tables of resistance and weights of copper wire at 20° C., pages 58 and 60.

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A No. 10 B. & S. copper wire has the following dimensions:

Diameter = 101.8971 mils.
Section = 10383.0 circular mils.

For drawing wire the dimensions from No. 0000 to No. 20 are given to the nearest mil, and for No. 21 and smaller to the nearest tenth of a mil. The table of comparative sizes gives the shop sizes of the B. & S. gauge.

It is impossible to draw a wire to an exact size. Ordinary practice is to draw a No. 10 B. & S. wire between 101 and 103 mils. The resulting wire may average 102 or 101.9 mils, or something different from either. A table calculated on the exact size is, therefore, as nearly right as though ordinary shop sizes were used. The weight and resistance of an actual wire will very seldom correspond with any table.

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PROPERTIES OF COPPER WIRE.

United States Units—Brown & Sharpe Gauge.

Numbers.	Diameter in mils.	Area in circular mils.	Weight in Pounds.		Resistance at 20° C—68° F.	
			1000 feet.	Mile.	1000 feet.	Mile.
0000	460.0	211 600.	640.5	3 382.	.049 0	.259
000	409.6	167 806.	507.9	2 682.	.061 8	.326
00	364.8	133 077.	402.8	2 127.	.077 9	.411
0	324.9	105 535.	319.5	1 687.	.098 3	.519
1	289.3	83 692.7	253.3	1 338.	.123 9	.654
2	257.6	66 371.3	200.9	1 061.	.156 3	.825
3	229.4	52 634.8	159.3	841.2	.197 0	1.040
4	204.3	41 741.3	126.4	667.1	.248 5	1.312
5	181.9	33 102.4	100.2	529.1	.313 3	1.654
6	162.0	26 251.4	79.46	419.6	.395 1	2.086
7	144.3	20 818.3	63.02	332.7	.498 2	2.630
8	128.5	16 509.7	49.97	263.9	.628 2	3.317
9	114.4	13 092.8	39.63	209.3	.792 1	4.182
10	101.9	10 383.0	31.43	165.9	.998 9	5.274
11	90.74	8 234.11	24.92	131.6	1.260	6.650
12	80.81	6 529.95	19.77	104.4	1.588	8.386
13	71.96	5 178.48	15.68	82.77	2.003	10.57
14	64.08	4 106.72	12.43	65.64	2.525	13.33
15	57.07	3 256.78	9.858	52.05	3.184	16.81
16	50.82	2 582.74	7.818	41.28	4.016	21.20
17	45.26	2 048.21	6.200	32.74	5.064	26.74
18	40.30	1 624.30	4.917	25.96	6.385	33.71
19	35.89	1 288.13	3.899	20.59	8.051	42.51
20	31.96	1 021.53	3.092	16 33	10.15	53.61
21	28.46	810.114	2.452	12.95	12.80	67.60
22	25.35	642.450	1.945	10.27	16.14	85.24
23	22.57	509.486	1.542	8.143	20.36	107.5
24	20.10	404.041	1.223	6.458	25.67	135.5
25	17.90	320.419	.9699	5.121	32.37	170.9
26	15.94	254.104	.7692	4.061	40.81	215.5
27	14.20	201.513	.6100	3.221	51.47	271.7
28	12.64	159.807	.4837	2.554	64.90	342.7
29	11.26	126.733	.3836	2.026	81.84	432.1
30	10.03	100.504	.3042	1.606	103.2	544.9
31	8.928	79.7031	.2413	1.274	130.1	687.0
32	7.950	63.2075	.1913	1.010	164.1	866.4
33	7.080	50.1258	.1517	.801	206.9	1 092.4
34	6.305	39.7516	.1203	.635	260.9	1 377.6
35	5.615	31.5244	.0954	.504	329.0	1 737.1
36	5.000	25.0000	.0757	.400	414.8	2 190.4
37	4.453	19.8259	.0600	.317	523.1	2 762.0
38	3.965	15.7227	.0476	.251	659.6	3 482 9
39	3.531	12.4686	.0377	.199	831.8	4 391.8
40	3.145	9.88807	.0299	.158	1049.0	5 538.0

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PROPERTIES OF COPPER WIRE.

Metric Units—Brown & Sharpe Gauge.

Numbers.	Diameter in millimeters.	Area in square millimeters.	Weight in kilograms per kilometer.	Resistance at 20° C—68° F. per kilometer.
0 000	11.68	107.2	953.2	.160 8
000	10.40	85.03	755.9	.202 8
00	9.266	67.43	599.5	.255 7
0	8.252	53.48	475.4	.322 4
1	7.348	42.41	377.0	.406 6
2	6.544	33.63	299.0	.512 7
3	5.827	26.67	237.1	.646 5
4	5.189	21.15	188.0	.815 2
5	4.621	16.77	149.1	1.028
6	4.115	13.30	118.3	1.296
7	3.665	10.55	93.78	1.634
8	3.264	8.366	74.37	2.061
9	2.906	6.634	58.98	2.599
10	2.588	5.261	46.77	3.277
11	2.305	4.172	37.09	4.132
12	2.053	3.309	29.42	5.211
13	1.828	2.624	23.33	6.571
14	1.628	2.081	18.50	8.285
15	1.450	1.650	14.67	10.45
16	1.291	1.309	11.63	13.17
17	1.150	1.038	9.226	16.61
18	1.024	.823 1	7.317	20.95
19	.911 6	.652 7	5.803	26.42
20	.811 8	.517 6	4.602	33.31
21	.723 0	.410 5	3.649	42.00
22	.643 8	.325 5	2.894	52.96
23	.573 3	.258 2	2.295	66.79
24	.510 6	.204 7	1.820	84.21
25	.454 7	.162 4	1.443	106.2
26	.404 9	.128 8	1.145	133.9
27	.360 6	.102 1	.907 7	168.9
28	.321 1	.080 98	.719 9	212.9
29	.285 9	.064 22	.570 9	268.5
30	.254 6	.050 93	.452 7	338.6
31	.226 8	.040 39	.359 0	426.9
32	.201 9	.032 03	.284 7	538.3
33	.179 8	.025 40	.225 8	678.8
34	.160 1	.020 14	.179 1	856.0
35	.142 6	.015 97	.142 0	1 079.4
36	.127 0	.012 67	.112 6	1 361.0
37	.113 1	.010 05	.089 3	1 716.2
38	.100 7	.007 97	.070 8	2 164.1
39	.089 7	.006 32	.056 2	2 728.9
40	.079 9	.005 01	.044 5	3 441.1

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PROPERTIES OF COPPER WIRE.

United States Units—New British Standard Gauge.

Numbers.	Diameter in mils.	Area in circular mils.	Weight in Pounds.		Resistance at 20° C—68° F.	
			1000 feet.	Mile.	1000 feet.	Mile.
0000 000	500.	250 000.	756.8	3 996.	.041 5	.219
000 000	464.	215 296.	651.7	3 441.	.048 2	.254
00 000	432.	186 624.	564.9	2 983.	.055 6	.293
0 000	400.	160 000.	484.3	2 557.	.064 8	.342
000	372.	138 384.	418.9	2 212.	.074 9	.396
00	348.	121 104.	366.6	1 936.	.085 6	.452
0	324.	104 976.	317.8	1 678.	.098 8	.522
1	300.	90 000.	272.4	1 438.	.115 2	.608
2	276.	76 176.	230.6	1 217.	.136 1	.719
3	252.	63 504.	192.2	1 015.	.163 3	.862
4	232.	53 824.	162.9	860.2	.192 7	1.017
5	212.	44 944.	136.0	718.3	.230 8	1.218
6	192.	36 864.	111.6	589.2	.281 3	1.485
7	176.	30 976.	93.76	495.1	.334 8	1.768
8	160.	25 600.	77.49	409.2	.405 1	2.139
9	144.	20 736.	62.77	331.4	.500 2	2.641
10	128.	16 384.	49.59	261.9	.633 0	3.342
11	116.	13 456.	40.73	215.1	.770 7	4.070
12	104.	10 816.	32.74	172.9	.958 9	5.063
13	92.	8 464.	25.62	135.3	1.225	6.470
14	80.	6 400.	19.37	102.3	1.620	8.556
15	72.	5 184.	15.69	82.85	2.001	10.56
16	64.	4 096.	12.40	65.46	2.532	13.37
17	56.	3 136.	9.493	50.12	3.307	17.46
18	48.	2 304.	6.974	36.82	4.501	23.77
19	40.	1 600.	4.843	25.57	6.482	34.22
20	36.	1 296.	3.923	20.71	8.002	42.25
21	32.	1 024.	3.098	16.37	10.13	53.48
22	28.	784.	2.373	12.53	13 23	69.85
23	24.	576.	1.744	9.206	18.01	95.07
24	22.	484.	1.465	7.736	21.43	113.1
25	20.	400.	1.211	6.393	25.93	136.9
26	18.	324.	.9807	5.178	32.01	169.0
27	16.4	268 96	.8141	4.299	38.56	203.6
28	14.8	219.04	.6630	3.501	47.35	250.0
29	13.6	184.96	.5599	2.956	56.07	296.1
30	12.4	153.76	.4654	2.457	67 45	356.1
31	11.6	134.56	.4078	2.151	77.07	407.0
32	10.8	116.64	.3531	1.864	88.92	469.5
33	10.0	100.	.3027	1.598	103.7	547.6
34	9.2	84.64	.2562	1.353	122.5	647.0
35	8.4	70.56	.2136	1.128	147.0	776.1
36	7.6	57.76	.1748	.923	179.6	948.1
37	6.8	46.24	.1400	.739	224.3	1 184.3
38	6.0	36.00	.1090	.575	288.1	1 521.1
39	5.2	27.04	.0819	.432	383.6	2 025.1
40	4.8	23.04	.0697	.368	450.1	2 376.7
50	1.0	1.00	.0030	.016	10371.2	54 759.9

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PROPERTIES OF COPPER WIRE.

United States Units—Birmingham Wire Gauge.

Numbers.	Diameter in mils.	Area in circular mils.	Weight in Pounds.		Resistance at 20° C—68° F.	
			1000 feet.	Mile.	1000 feet.	Mile.
0000	454.	206 116.	623.9	3 294.	.050 3	.266
000	425.	180 625.	546.8	2 887.	.057 4	.303
00	380.	144 400.	437.1	2 308.	.071 8	.379
0	340.	115 600.	349.9	1 848.	.089 7	.474
1	300.	90 000.	272.4	1 438.	.115 2	.608
2	284.	80 656.	244.1	1 289.	.128 6	.679
3	259.	67 081.	203.1	1 072.	.154 6	.816
4	238.	56 644.	171.5	905.3	.183 1	.967
5	220.	48 400.	146.5	773.6	.214 3	1.131
6	203.	41 209.	124.7	658.6	.251 7	1.329
7	180.	32 400.	98.07	517.8	.320 1	1.690
8	165.	27 225.	82.41	435.1	.380 9	2.011
9	148.	21 904.	66.30	350.1	.473 5	2.500
10	134.	17 956.	54.35	287.0	.577 6	3.050
11	120.	14 400.	43.59	230.1	.720 2	3.803
12	109.	11 881.	35.96	189.9	.872 9	4.609
13	95.	9 025.	27.32	144.2	1.149	6.068
14	83.	6 889.	20.85	110.1	1.505	7.949
15	72.	5 184.	15.69	82 85	2.001	10.56
16	65	4 225.	12.79	67.53	2.455	12.96
17	58.	3 364.	10.18	53.77	3.083	16.28
18	49.	2 401.	7.268	38.37	4.320	22.81
19	42.	1 764.	5.340	28.19	5.879	31.04
20	35.	1 225.	3.708	19.58	8.466	44.70
21	32.	1 024.	3.100	16.37	10.13	53.48
22	28.	784.	2.373	12.53	13.23	69.85
23	25.	625.	1.892	9.989	16.59	87.62
24	22.	484.	1.465	7.736	21.43	113.1
25	20.	400.	1.211	6.393	25.93	136.9
26	18.	324.	.980 7	5.178	32.01	169.0
27	16.	256.	.774 9	4.092	40 51	213.9
28	14.	196.	.593 3	3.133	52.91	279.4
29	13.	169.	.511 6	2.701	61.37	324.0
30	12.	144.	.435 9	2.301	72.02	380.3
31	10.	100.	.302 7	1.598	103.7	547.6
32	9.	81.	.245 2	1.295	128.0	676.0
33	8.	64.	.193 7	1.023	162.1	855.6
34	7.	49.	.148 3	.783	211.7	1 117.5
35	5.	25.	.075 7	.400	414.8	2 190.4
36	4.	16.	.048 4	.256	648.2	3 422.5

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SPECIFICATIONS FOR COPPER WIRE.

The American Society for Testing Materials have published specifications for—

Hard or Unannealed Copper Wire.
Medium Hard Copper Wire.
Soft or Annealed Copper Wire.

The tables on pages 81 and 82 are taken from these specifications.

Allowable variations from nominal sizes.—For hard and medium hard copper wire the variation is 1% either way, provided no variation of less than one mil is used. For soft or annealed copper wire the allowable variation is 1% either way, provided no variation of less than one-tenth mil is used.

The tensile strength and elongation shall be at least equal to the value stated on page 82. The elongation of wire .204″ in diameter and smaller shall be determined by measurements made between the jaws of the testing machine.

The fracture shall be between the bench marks in the case of wire larger than .204″ in diameter, and between the jaws in the case of smaller wire, and not closer than 1″ to either bench mark or jaw.

The elongation for hard copper wire and medium hard copper wire is taken in ten inches for sizes larger than .204″, and in sixty inches for sizes .204″ and smaller. For soft or annealed copper wire the elongation is taken in ten inches on all sizes.

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COPPER WIRE SPECIFICATIONS.

OHMS AT 20° C.

No.	Conductivity.	Mile pound.	Meter gram.	Microhms per cm cube.	Microhms per Inch cube.	Mil foot.
1	98.2	891.58	.15614	1.7564	.69150	10.565
2	97.7	896.15	.15694	1.7654	.69504	10.619
3	96.7	905.44	.15857	1.7837	.70224	10.729
4	97.2	900.77	.15775	1.7745	.69863	10.674
5	96.2	910.15	.15940	1.7930	.70590	10.785
6	100.0	875.20	.15328	1.7241	.67879	10.371

1 = Soft Copper.
2 = Medium Hard Copper, 0000 to 0 B. & S.
3 = Medium Hard Copper, 1 to 18 B. & S.
4 = Hard Drawn Copper, 0000 to 0 B. & S.
5 = Hard Drawn Copper, 1 to 18 B. & S.
6 = Standard values.

$$\text{Conductivity} = \frac{875.20}{\text{mile ohm.}}$$

In the table opposite, the elongation in hard and medium hard copper, 0000 to 3 is taken in 10″; for 4 and smaller in 60″.

The elongation in soft copper is taken in 10″ for all sizes.

Elastic Limit for Hard Drawn Copper.

0000 to 0 averages 55% and should not be less than 50% of the ultimate breaking strength as given in the table.

1 to 18 averages 60% and should not be less than 55% of the ultimate breaking strength as given in the table.

The maximum strength per square inch of medium hard drawn copper is 7000 pounds more than the minimum stength given in the table.

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TENSILE STRENGTH OF COPPER WIRE.

B. & S. Gauge.	Hard.			Medium Hard.				Soft.		
	Breaking weight.	Elongation per cent.	Pounds square inch.	Breaking weight. Minimum.	Breaking weight. Maximum.	Elongation per cent.	Pounds square inch.	Breaking weight.	Elongation 10".	Pounds square inch.
0000	8143	3.75	49000	6980	8143	3.75	42000	5983	35	36000
000	6722	3.25	51000	5668	6590	3.60	43000	4755	35	36000
00	5519	2.80	52800	4599	5330	3.25	44000	3763	35	36000
0	4517	2.40	54500	3730	4310	3.00	45000	2984	35	36000
1	3688	2.17	56100	3024	3484	2.75	46000	2432	30	37000
2	3003	1.98	57600	2450	2815	2.50	47000	1929	30	37000
3	2439	1.79	59000	1984	2274	2.25	48000	1530	30	37000
4	1970	1.24	60100	1584	1814	1.25	48330	1213	30	37000
5	1591	1.18	61200	1264	1446	1.20	48600	962	30	37000
6	1280	1.14	62100	1010	1155	1.15	49000	763	30	37000
7	1030	1.09	63000	807	921	1.11	49330	605	30	37000
8	826	1.06	63700	644	735	1.08	49660	480	30	37000
9	661	1.02	64300	514	586	1.06	50000	380	30	37000
10	529	1.00	64900	410	468	1.04	50330	314	25	38500
11	423	.97	65400	328	373	1.02	50660	249	25	38500
12	337	.95	65700	262	297	1.00	51000	197	25	38500
13	268	.92	65900	209	237	.98	51330	157	25	38500
14	214	.90	66200	167	189	.96	51660	124	25	38500
15	170	.89	66400	133	151	.94	52000	98	25	38500
16	135	.87	66600	106	120	.92	52330	78	25	38500
17	107	.86	66800	85	96	.90	52660	62	25	38500
18	85	.85	67000	68	77	.88	53000	49	25	33500

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STRANDED COPPER WIRES.

A WIRE ROD, sometimes called a ROD, is formed by hot rolling and is usually made into wire by cold drawing or rolling.

A WIRE is an extended filament of metal

A STRAND consists of several wires around a common axis.

A RIGHT-LAY STRAND is one in which the wires go in the same way as the threads of a right-hand screw. Holding the strand in front of you, and looking along the top of it, the wires go to the right.

A LEFT-LAY STRAND is one in which the wires go in the same way as the threads of a left-hand screw. Holding the strand in front of you, and looking along the top of it, the wires go to the left.

A PERFECT STRAND is made by twisting around one wire as a center, six wires; around this twelve wires, eighteen wires, twenty-four wires and so on. 7, 19, 37, 61, 91 or 127 wires form perfect strands.

A CONCENTRIC STRAND is a strand composed of a central core surrounded by one or more layers of helically laid wires.

The LAY of a strand is the length of the helix, measured parallel with the axis of the strand, which each wire forms around the center of the strand.

A LAYER is a number of wires, each of which is equally distant at all points from the center of the strand. In a perfect strand, six wires, twelve wires, and eighteen wires form layers.

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The lay depends on the diameter of the wires and the number in a layer. The lay may be expressed by the formula—

$$\text{Lay} = k\,n\,d$$

k = constant.
n = number of wires in a layer.
d = diameter of each wire.

A ROPE consists of several strands twisted together.

A rope of copper wire may be made in many forms, say seven strands of nineteen wires each, or nineteen strands of seven wires each. It is most convenient to use as a basis for ropes for electrical conductors a strand of seven wires. There are, therefore, the following forms:

7 × 7 or 49 wires, O D = 9d
19 × 7 or 133 wires, O D = 15d
37 × 7 or 259 wires, O D = 21d
61 × 7 or 427 wires, O D = 27d
91 × 7 or 637 wires, O D = 33d
127 × 7 or 889 wires, O D = 39d

If the strands are right-lay, the rope is usually made left-lay and vice versa. These ropes are called flexibles.

To summarize, there are wires, strands made of wires, and ropes made of strands. Conductor is a general term including all three.

CABLE.—The word "cable" suggests a composite structure. The meaning can be best illustrated by examples.

A submarine cable consists of an electrical conductor surrounded by a waterproof insulation, jute bedding, and a layer of iron armor wires.

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A telephone cable consists of copper wires insulated with paper, twisted together in pairs, and a number of these pairs twisted into a strand and covered with a lead pipe.

Electric light or power cables consist of an electrical conductor, insulated and lead encased.

We speak of rubber covered wires and cables. This is not exactly in keeping with the other uses of the word "cable."

Here CABLE seems to refer to the stranded conductor in whatever form it may be. A cable in this sense is an electrical conductor, consisting of several copper wires twisted together. Thus a cable may be either a strand or a rope.

Stranding.

The system of stranding which has been developed in this country calls for strands equal to the regular sizes, as far as they go; for sizes larger than No. 0000 B. & S. the area in circular mils is given.

In order to make No. 0000 B. & S. of nineteen wires, each wire must be .1055, and this is a special size wire. Nineteen No. 10 wires make the strand a little small.

There are two ways of handling this method of stranding. One is to use the perfect strand of one, seven, nineteen, thirty-seven, sixty-one, ninety-one, or one hundred twenty-seven wires, and draw the wires to correspond to this construction or else, by varying the number, to make strands of regular sized wire. 97.1 wires each No. 14 B. & S. equals 400,000 C. M. Ninety-seven wires do not lay up nicely, and a strand made in this way is always

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larger than the perfect strand of the same area. Sometimes wires have to be left out and all sorts of expedients have to be resorted to in order to get the proper sized strand out of regular sized wires.

We can begin a strand with two wires laying in two smaller wires to fill out, with three wires, with four wires with a center to hold the four wires in place, or with five wires with a center a little smaller than the wires. We can also use seven wires as the second layer, making the center a larger wire, a strand of three wires, or a strand of seven wires.

The details of this sort of stranding are not of any particular interest, but are resorted to sometimes at the factory in order to avoid the delay that comes from ordering special wire.

Strands may be built up of two sizes of wire, or even more. We may make 2,000,000 C. M. out of ninety-one wires of one size and thirty of another, laid up 1, 6, 12, 18, 24, 30, and 30 wires in each successive layer.

Lay of Strands.

With $k = 5$ the twist in a strand is about 2%. This means an increase of 2% in weight over a solid wire, and about the same increase in resistance. From experiments we have made, it looks as though the current follows the wires instead of passing freely from wire to wire parallel to the axis of the strand. In a rope the lay of the wires is about 2% and of the strands another 2%, making 4% in all.

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The resistance of a strand is figured about 2% more than the resistance of the individual wires divided by the number of wires, and for a rope 4% more.

Number of Wires in Strands.

The American Institute of Electrical Engineers approved the following stranding, June, 1915:

Circular Mils.	A	B	C
2,000,000	91	91	127
1,500,000	61	61	91
1,000,000	61	61	61
600,000	37	37	61
500,000	37	37	37
400,000	19	19	37
0000	7	19	19
00	7	7	19
2	7	7	7
6	7	7	7
7			7

Intermediates take the stranding of the next larger size.

A = Bare Strands.
B = Weatherproof Insulated Strands.
C = Rubber and Cambric Insulated Strands.

These strands require special sized wires, but for ropes or flexibles B. & S. sizes are used.

Flexible Stranding.

The table on the following page gives their recommendations for flexible stranding, using B. & S. wires.

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FLEXIBLES.

Stranding.	No. B. & S.	Diam.	C. M.	Weight, 1000 feet.	Ohms per 1000 feet at 68°.	Nearest size.
61 x 7	16	1.372	1,102,830	3 472.	.0098	1,000
"	17	1.222	874,586	2 753.	.0123	875
"	18	1.088	693,576	2 183.	.0156	700
"	19	.969	550,032	1 732.	.0196	550
"	20	.863	436,193	1 373.	.0247	450
"	21	.768	345,919	1 089.	.0312	350
"	22	.684	274,326	863.6	.0393	275
37 x 7	20	.671	264,576	832.9	.0408	250
"	21	.598	209,820	660.5	.0514	0000
"	22	.532	166,395	523.8	.0648	000
19 x 7	20	.479	135,863	427.7	.0794	00
"	21	.427	107,745	339.2	.1001	0
"	22	.380	85,446	269.0	.1262	1
"	23	.339	67,762	213.3	.1592	2
"	24	.302	53,737	169.2	.2007	3
7 x 7	21	.256	39,696	125.0	.2717	4
"	22	.228	31,480	99.10	.3426	5
"	23	.203	24,965	78.59	.4320	6
"	24	.181	19,798	62.33	.5448	7

The exact size cannot be obtained in this way. A No. 0000 flexible is made of 37 x 7 x 21 B. & S. wires, but to be exact a 0000 should be made of 261 x 21 B. & S. wires.

The nearest regular stranding, and the true number of wires to make exact stranding, B. & S., are

61 × 7 = 427, should be 415, or + 2.9%.
37 × 7 = 259, should be 261, or − .8%.
19 × 7 = 133, should be 130, or + 2.3%.
7 × 7 = 49, should be 52, or − 5.8%,

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Formulas for Strands.

Let d = the diameter of a wire in mils.
n = the number of wires.
C. M. = the area of the conductor in circular mils.

Then, $C.\ M. = d^2\ n$ $\qquad d = \sqrt{\frac{C.\ M.}{n}}$

$$n = \frac{C.\ M.}{d^2}$$

Concentric Strands.

$$\text{Ohms per 1000 feet} = \frac{10\ 578.6}{C.\ M.}$$

$$\text{Ohms per mile} = \frac{55\ 855.1}{C.\ M.}$$

$$\text{Ohms per kilometer} = \frac{34\ 706.7}{C.\ M.}$$

Pounds per 1000 feet = C. M. × .003 087 53
Pounds per mile = C. M. × .016 302 2
Kilograms per kilometer = C. M. × .004 594 74

These constants are 2% greater than those for solid conductors.

Ropes or Flexibles.

$$\text{Ohms per 1000 feet} = \frac{10\ 786.0}{C.\ M.}$$

$$\text{Ohms per mile} = \frac{56\ 950.3}{C.\ M.}$$

$$\text{Ohms per kilometer} = \frac{35\ 387.2}{C.\ M.}$$

Pounds per 1000 feet = C. M. × .003 148 07
Pounds per mile = C. M. × .016 621 8
Kilograms per kilometer = C. M. × .004 684 83

These constants are 4% greater than those for solid conductors.

In the tables the last three ciphers are omitted in the column giving circular mils; 3 000 means 3 000 000.

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CONCENTRIC STRANDS.

Circular mils.	Diameter.		Weight.		
	Inches.	Millimeters.	Lbs. per 1 000 feet.	Kg. per Km.	Lbs. per mile.
3 000	1.998	50.8	9 263	13 784	48 906
2 750	1.914	48.6	8 491	12 636	44 831
2 500	1.824	46.3	7 719	11 487	40 755
2 250	1.729	43.9	6 947	10 338	36 680
2 000	1.630	41.4	6 175	9 189	32 604
1 950	1.610	40.9	6 021	8 960	31 789
1 900	1.590	40.4	5 866	8 730	30 974
1 850	1.569	39.9	5 712	8 500	30 159
1 800	1.547	39.3	5 558	8 271	29 344
1 750	1.526	38.8	5 403	8 041	28 529
1 700	1.504	38.2	5 249	7 811	27 714
1 650	1.482	37.6	5 094	7 581	26 899
1 600	1.459	37.1	4 940	7 352	26 083
1 550	1.436	36.5	4 786	7 122	25 268
1 500	1.412	35.9	4 631	6 892	24 453
1 450	1.388	35.3	4 477	6 662	23 638
1 400	1.364	34.6	4 323	6 433	22 823
1 350	1.340	34.1	4 168	6 203	22 008
1 300	1.315	33.4	4 014	5 973	21 193
1 250	1.289	32.7	3 859	5 743	20 378
1 200	1.263	32.1	3 705	5 514	19 563
1 150	1.236	31.4	3 551	5 284	18 747
1 100	1.209	30.7	3 396	5 054	17 932
1 050	1.181	30.0	3 242	4 824	17 117
1 000	1.152	29.3	3 088	4 595	16 302
950	1.123	28.5	2 933	4 365	15 487
900	1.094	27.8	2 779	4 135	14 672
850	1.062	27.0	2 624	3 906	13 857
800	1.031	26.2	2 470	3 676	13 042
750	.998	25.3	2 316	3 446	12 227
700	.964	24.5	2 161	3 216	11 412
650	.929	23.6	2 007	2 987	10 596
600	.893	22.7	1 853	2 757	9 781
550	.855	21.7	1 698	2 527	8 966
500	.813	20.7	1 544	2 297	8 151
450	.772	19.6	1 389	2 068	7 336
400	.728	18.5	1 235	1 838	6 521
350	.681	17.3	1 080	1 608	5 706
300	.630	16.0	926	1 378	4 891
250	.575	14.6	772	1 149	4 076

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CONCENTRIC STRANDS—Cont.

Ohms at 68° F.			Area.		
1 000 feet.	Kilometer.	Mile.	Square milli-meters.	Square inches.	C. M.
.00353	.01157	.01862	1 520.1	2.356	3 000
.00385	.01262	.02031	1 393.5	2.160	2 750
.00423	.01388	.02234	1 266.8	1.963	2 500
.00470	.01543	.02482	1 140.1	1.767	2 250
.00529	.01735	.02793	1 013.4	1.571	2 000
.00542	.01780	.02864	988.1	1.532	1 950
.00557	.01827	.02940	962.7	1.492	1 900
.00572	.01876	.03019	937.4	1.453	1 850
.00588	.01928	.03103	912.1	1.414	1 800
.00604	.01983	.03192	886.7	1.374	1 750
.00622	.02042	.03286	861.4	1.335	1 700
.00641	.02103	.03385	836.1	1.296	1 650
.00661	.02169	.03491	810.7	1.257	1 600
.00682	.02239	.03604	785.4	1.217	1 550
.00705	.02314	.03724	760.1	1.178	1 500
.00730	.02394	.03852	734.7	1.139	1 450
.00756	.02479	.03990	709.4	1.100	1 400
.00784	.02571	.04137	684.1	1.060	1 350
.00814	.02670	.04297	658.7	1.021	1 300
.00846	.02777	.04468	633.4	.982	1 250
.00882	.02892	.04655	608.1	.942	1 200
.00920	.03018	.04857	582.7	.903	1 150
.00962	.03155	.05078	557.4	.864	1 100
.01007	.03305	.05320	532.0	.825	1 050
.01058	.03471	.05586	506.7	.785	1 000
.01114	.03653	.05879	481.4	.746	950
.01175	.03856	.06206	456.0	.707	900
.01245	.04083	.06571	430.7	.668	850
.01322	.04338	.06982	405.4	.628	800
.01410	.04628	.07447	380.0	.589	750
.01511	.04958	.07979	354.7	.550	700
.01627	.05339	.08593	329.4	.511	650
.01763	.05784	.09309	304.0	.471	600
.01923	.06310	.10155	278.7	.432	550
.02116	.06941	.11171	253.4	.393	500
.02351	.07712	.12412	228.0	.353	450
.02645	.08677	.13964	202.7	.314	400
.03022	.09916	.15959	177.3	.275	350
.03526	.11569	.18618	152.0	.236	300
.04231	.13883	.22342	126.7	.196	250

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CONCENTRIC STRANDS.

No. B. & S.	Diameter.		Weight.			Ohms at 68° F.			Area.		
	Inches.	Milli-meters.	Pounds per 1000 feet.	Kilograms per kilometer.	Pounds per Mile.	1000 feet.	Kilometer.	Mile.	Square milli-meters.	Square Inches.	C. M.
0000	.528	13.40	653.3	972.2	3450.	.049 99	.164 02	.263 97	107.2	.166	211 600
000	.470	11.94	518.1	771.0	2736.	.063 04	.206 83	.332 86	85.0	.132	167 806
00	.419	10.63	410.9	611.5	2169.	.079 49	.260 80	.419 72	67.4	.105	133 077
0	.373	9.36	325.8	484.9	1720.	.100 24	.328 86	.529 26	53.5	.0829	105 535
1	.328	8.33	258.4	384.5	1364.	.126 40	.414 69	.667 38	42.4	.0657	83 692.7
2	.292	7.42	204.9	305.0	1082.	.159 39	.522 92	.841 55	33.6	.052 1	66 371.3
3	.260	6.61	162.5	241.8	858.1	.200 98	.659 39	1.061 2	26.7	.041 3	52 634.8
4	.232	5.88	128.9	191.8	680.5	.253 43	.831 47	1.338 1	21.2	.032 8	41 741.3
5	.206	5.24	102.2	152.1	539.6	.319 57	1.048 5	1.687 3	16.8	.026 0	33 102.4
6	.184	4.66	81.05	120.6	428.0	.402 97	1.322 1	2.127 7	13.3	.020 6	26 251.4
8	.146	3.70	50.97	75.86	269.1	.640 75	2.102 2	3.383 2	8.4	.013 0	16 509.7
9	.130	3.29	49.42	60.16	213.4	.807 97	2.650 8	4.266 1	6.6	.010 3	13 092.8
10	.116	2.93	32.06	47.71	169.3	1.018 8	3.342 6	5.379 5	5.3	.008 2	10 383.0
12	.092	2.32	20.16	30.00	106.5	1.620 0	5.315 0	8.553 7	3.3	.005 1	6 529.95
14	.073	1.84	12.68	18.87	66.95	2.575 9	8.451 2	13.601	2.1	.003 2	4 106.72
16	.058	1.47	7.974	11.87	42.10	4.095 9	13.43 8	21.626	1.3	.002 0	2 582.74
18	.045	1.15	5.015	7.463	26.48	6.512 7	21.36 7	34.387	.82	.001 3	1 624.30
20	.036	.92	3.154	4.694	16.65	10.356	33.975	54.678	.52	.000 8	1 021.53
22	.029	.73	1.984	2.952	10.47	16.466	54.022	86.941	.33	.000 6	642.450

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FLEXIBLES.

No. B. & S.	Diameter.		Weight.			Ohms at 68° F.			Area.		
	Inches.	Milli-meters.	Pounds per 1000 feet.	Kilograms per kilometer.	Pounds per mile.	1000 feet.	Kilometer.	Mile.	Square milli-meters.	Square Inches.	C. M.
0000	.599	15.20	666.1	991.3	3 517.	.050 97	.167 24	.269 14	107.2	.166	211 600.
000	.533	13.53	528.3	786.1	2 789.	.064 28	.210 88	.339 38	85.0	.132	167 806.
00	.469	11.91	418.9	623.4	2 212.	.081 05	.265 91	.427 95	67.4	.105	133 077.
0	.418	10.61	332.2	494.4	1 754.	.102 20	.335 31	.539 63	53.5	.082 9	105 535.
1	.372	9.44	263.5	392.1	1 391.	.128 88	.422 82	.680 47	42.4	.065 7	83 692.7
2	.332	8.44	208.9	310.9	1 103.	.162 51	.533 17	.858 06	33.6	.052 1	66 371.3
3	.294	7.48	165.7	246.6	874.9	.204 92	.672 31	1.082 0	26.7	.041 3	52 634.8
4	.262	6.65	131.4	195.6	693.8	.258 40	.847 77	1.364 4	21.2	.032 8	41 741.3
5	.234	5.94	104.2	155.1	550.2	.325 84	1.069 0	1.720 4	16.8	.026 0	33 102.4
6	.208	5.28	82.64	123.0	436.3	.410 88	1.348 0	2.169 4	13.3	.020 6	26 251.4
7	.185	4.71	65.54	97.53	346.0	.518 10	1.699 8	2.735 6	10.6	.016 4	20 818.3
8	.165	4.18	51.97	77.35	274.4	.653 32	2.143 4	3.449 5	8.4	.013 0	16 509.7
9	.147	3.73	41.22	61.34	217.6	.823 82	2.702 8	4.349 7	6.6	.010 3	13 092.8

NUMBER OF WIRES IN STRANDS.

Circular mils.	B. & S. G.																
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2 000 000	121	153	193	243	306	386	487	614	774	976	1231	1553	1958	2469	3113	3926	4950
1 750 000	106	134	169	213	268	338	426	537	678	854	1077	1359	1713	2160	2724	3435	4331
1 500 000	91	115	144	182	230	290	365	461	581	732	923	1164	1468	1852	2335	2944	3712
1 250 000	76	95	120	152	191	241	304	384	484	610	770	970	1224	1543	1946	2453	3094
1 000 000	61	76	96	121	153	193	244	307	387	488	616	776	979	1234	1557	1963	2475
950 000	58	73	91	115	145	183	231	292	368	464	585	738	930	1173	1479	1865	2351
900 000	55	69	87	109	138	174	219	276	348	439	554	699	881	1111	1401	1766	2227
850 000	51	65	82	103	130	164	207	261	329	415	523	660	832	1049	1323	1668	2104
800 000	48	61	77	97	123	154	195	246	310	391	493	621	783	988	1245	1570	1980
750 000	45	57	72	91	115	145	183	230	290	366	462	582	734	926	1167	1472	1856
700 000	42	53	67	85	107	135	170	215	271	342	431	543	685	864	1090	1374	1732
650 000	39	50	63	79	100	126	158	200	252	317	400	505	636	802	1012	1276	1609
600 000	36	46	58	73	92	116	146	184	232	293	369	466	587	741	934	1178	1485
550 000	33	42	53	67	84	106	134	169	213	269	339	427	538	679	856	1080	1361
500 000	30	38	48	61	77	97	122	154	194	244	308	388	489	617	778	981	1237
450 000	27	34	43	55	69	87	110	138	174	220	277	349	441	555	700	883	1114
400 000	24	31	39	49	61	77	97	123	155	195	246	311	392	494	623	785	990
350 000	21	27	34	43	54	68	85	107	136	171	215	272	343	432	545	687	866
300 000	18	23	29	36	46	58	73	92	116	146	185	233	294	370	467	589	742
250 000	15	19	24	30	38	48	61	77	97	122	154	194	245	309	389	491	619

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NUMBER OF WIRES IN STRANDS.

Size strand.	Number B. & S. G.																
	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
0000	207	261	330	415	524	660	833	1050	1324	1670	2106	2655	3348	4220	5324	6712	8464
000	164	207	261	330	415	524	660	833	1050	1324	1670	2106	2655	3348	4220	5324	6712
00	130	164	207	261	330	415	524	660	833	1050	1324	1670	2106	2655	3348	4220	5324
0	103	130	164	207	261	330	415	524	660	833	1050	1324	1670	2106	2655	3348	4220
1	82	103	130	164	207	261	330	415	524	660	833	1050	1324	1670	2106	2655	3348
2	65	82	103	130	164	207	261	330	415	524	660	833	1050	1324	1670	2106	2655
3	52	65	82	103	130	164	207	261	330	415	524	660	833	1050	1324	1670	2106
4	41	52	65	82	103	130	164	207	261	330	415	524	660	833	1050	1324	1670
5	32	41	52	65	82	103	130	164	207	261	330	415	524	660	833	1050	1324
6	26	32	41	52	65	82	103	130	164	207	261	330	415	524	660	833	1050
8	16	20	26	32	41	52	65	82	103	130	164	207	261	330	415	524	660
9	13	16	20	26	32	41	52	65	82	103	130	164	207	261	330	415	524
10	10	13	16	20	26	32	41	52	65	82	103	130	164	207	261	330	415
12	6.4	8	10	13	16	20	26	32	41	52	65	82	103	130	164	207	261
14	4.0	5.1	6.4	8	10	13	16	20	26	32	41	52	65	82	103	130	164
16	2.5	3.2	4.0	5.1	6.4	8	10	13	16	20	26	32	41	52	65	82	103
18	1.6	2.0	2.5	3.2	4.0	5.1	6.4	8	10	13	16	20	26	32	41	52	65
20	1.0	1.3	1.6	2.0	2.5	3.2	4.0	5.1	6.4	8	10	13	16	20	26	32	41
22	.....	.....	1.0	1.3	1.6	2.0	2.5	3.2	4.0	5.1	6.4	8	10	13	16	20	26

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DIAMETER OF WIRES IN CONCENTRIC STRANDS.

Area in C. M.	Number of Wires.								
	1	7	19	37	61	91	127	169	217
3 000	1732.	654.6	397.4	284.8	221.8	181.6	153.7	133.2	117.6
2 750	1658.	626.8	380.4	272.6	212.3	173.8	147.2	127.5	112.6
2 500	1581.	597.6	362.7	259.9	202.4	165.7	140.3	121.6	107.3
2 250	1500.	566.9	344.1	246.6	192.1	157.2	133.1	115.4	101.8
2 000	1414.	534.5	324.4	232.5	181.1	148.2	125.5	108.8	96.0
1 950	1396.	527.8	320.4	229.6	178.8	146.4	123.9	107.4	94.8
1 900	1378.	521.0	316.2	226.6	176.5	144.5	122.3	106.0	93.6
1 850	1360.	514.1	312.0	223.6	174.1	142.6	120.7	104.6	92.3
1 800	1342.	507.1	307.8	220.6	171.8	140.6	119.1	103.2	91.1
1 750	1323.	500.0	303.5	217.5	169.4	138.7	117.4	101.7	89.8
1 700	1304.	492.8	299.1	214.4	166.9	136.7	115.7	100.3	88.5
1 650	1285.	485.5	294.7	211.2	164.5	134.7	114.0	98.8	87.2
1 600	1265.	478.1	290.2	208.0	162.0	132.6	112.2	97.3	85.9
1 550	1245.	470.6	285.6	204.7	159.4	130.5	110.5	95.8	84.5
1 500	1225.	462.9	281.0	201.3	156.8	128.4	108.7	94.2	83.1
1 450	1204.	455.1	276.3	198.0	154.2	126.2	106.9	92.6	81.7
1 400	1183.	447.2	271.4	194.5	151.5	124.0	105.0	91.0	80.3
1 350	1162.	439.2	266.6	191.0	148.8	121.8	103.1	89.4	78.9
1 300	1140.	430.9	261.6	187.4	146.0	119 5	101.2	87.7	77.4
1 250	1118.	422.6	256.5	183.8	143.1	117.2	99.2	86 0	75.9
1 200	1095.	414.0	251.3	180.1	140.3	114.8	97.2	84.3	74.4
1 150	1072.	405.3	246.0	176.3	137.3	112.4	95.2	82.5	72.8
1 100	1049.	396.4	240.6	172.4	134.3	109.9	93.1	80.7	71.2
1 050	1025.	387.3	235.1	168.5	131.2	107.4	90.9	78.8	69.6
1 000	1000.	378.0	229.4	164.4	128.0	104.8	88.7	76.9	67.9
950	975.	368.4	223.6	160.2	124.8	102.2	86.5	75.0	66.2
900	949.	358.6	217.6	156.0	121.5	99.4	84.2	73.0	64.4
850	922.	348.5	211.5	151.6	118.0	96.6	81.8	70.9	62.6
800	894.	338.1	205.2	147.0	114.5	93.8	79.4	68.8	60.7
750	866.	327.3	198.7	142.4	110.9	90.8	76.8	66.6	58.8
700	837.	316.2	191.9	137.5	107.1	87.7	74.2	64.4	56.8
650	806.	304.7	185.0	132.5	103.2	84.5	71.5	62.0	54.7
600	775.	292.8	177.7	127.3	99.2	81.2	68.7	59.6	52.6
550	742.	280.3	170.1	121.9	95.0	77.7	65.8	57.0	50.3
500	707.	267.3	162.2	116.2	90.5	74.1	62.7	54.4	48.0
450	671.	253.5	153.9	110.3	85.9	70.3	59.5	51.6	45.5
400	632.	23 .0	145.1	104.0	81.0	66.3	56.1	48.6	42.9
350	592.	223.6	135.7	97.3	75.7	62.0	52.5	45.5	40.2
300	548.	207.0	125.7	90.0	70.1	57.4	48.6	42.1	37.2
250	500.	189.0	114.7	82.2	64.0	52.4	44.4	38.5	33.9
225	474.	179.3	108.8	78.0	60.7	49.7	42.1	36.5	32.2
200	447.	169.0	102.6	73.5	57.3	46.9	39.7	34.4	30.4
150	387.	146.4	88.9	63.7	49.6	40.6	34.4	29.8	26.3
100	316.	119.5	72.5	52.0	40.5	33.1	28.1	24.3	21.5
Factor	1	3	5	7	9	11	13	15	17

DIAMETER OF WIRES IN FLEXIBLES.

Area in C. M.	Number of Seven Wire Strands.					
	7	19	37	61	91	127
3 000	247.4	150.2	107.6	83.8	68.6	58.1
2 750	236.9	143.8	103 0	80.3	65.7	55.6
2 500	225.9	137.1	98.2	76.5	62.6	53.0
2 250	214.3	130.1	93.2	72.6	59.4	50.3
2 000	202.0	122.6	87.9	68.4	56.0	47.4
1 950	199.5	121.1	86.8	67.6	55.3	46.8
1 900	196.9	119.5	85.6	66.7	54.6	46.2
1 850	194.3	117.9	84.5	65.8	53.9	45.6
1 800	191.7	116.3	83.4	64.9	53.2	45.0
1 750	189.0	114.7	82.2	64.0	52.4	44.4
1 700	186.3	113.1	81.0	63.1	51.7	43.7
1 650	183.5	111.4	79.8	62.2	50.9	43.1
1 600	180.7	109.7	78.6	61.2	50.1	42.4
1 550	177.9	108.0	77.4	60.2	49.3	41.8
1 500	175.0	106.2	76.1	59.3	48.5	41.1
1 450	172.0	104.4	74.8	58.3	47.7	40.4
1 400	169.0	102.6	73.5	57.3	46.9	39.7
1 350	166.0	100.7	72.2	56.2	46.0	39.0
1 300	162.9	98.9	70.8	55.2	45.2	38.2
1 250	159.7	96.9	69.5	54.1	44.3	37.5
1 200	156.5	95.0	68.1	53.0	43.4	36.7
1 150	153.2	93.0	66.6	51.9	42.5	36.0
1 100	149.8	90.9	65.2	50.8	41.6	35.2
1 050	146.4	88.9	63.7	49.6	40.6	34.4
1 000	142.9	86.7	62.1	48.4	39.6	33.5
950	139.2	84.5	60.6	47.2	38.6	32.7
900	135.5	82.3	58.9	45.9	37.6	31.8
850	131.7	79.9	57.3	44.6	36.5	31.0
800	127.8	77.6	55.6	43.3	35.4	30.0
750	123.7	75.1	53.8	41.9	34.3	29.0
700	119.5	72.5	52.0	40.5	33.1	28.1
650	115.2	69.9	50.1	39.0	31.9	27.0
600	110.7	67.2	48.1	37.5	30.7	26.0
550	105.9	64.3	46.1	35.9	29.4	24.9
500	101.0	61.3	43.9	34.2	28.0	23.7
450	95.8	58.2	41.7	32.5	26.6	22.5
400	90.4	54.8	39.3	30.6	25.1	21.2
350	84.5	51.3	36.8	28.6	23.4	19.8
300	78.2	47.5	34.0	26.5	21.7	18.4
250	71.4	43.4	31.1	24.2	19.8	16.8
225	67.8	41.4	29.5	23.0	18.8	15.9
200	63.9	38.8	27.8	21.6	17.7	15.0
150	55.3	33.6	24.1	18.7	15.3	13.0
100	45.2	27.4	19.6	15.3	12.5	10.6
Factor	9	15	21	27	33	39

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DIAMETER OF WIRES IN CONCENTRIC STRANDS.

No. B. & S.	Number of Wires.								
	1	7	19	37	61	91	127	169	217
0000	460.	173.9	105.5	75 6	58.9	48.2	40.8	35·4	31.2
000	410.	154.8	94.0	67.3	52.4	42.9	36.4	31.5	27.8
00	365.	137.9	83 7	60.0	46.7	38.2	32.4	28.1	24.8
0	325.	122.8	74 5	53.4	41.6	34 1	28.8	25.0	22.1
1	289.	109.3	66.4	47.6	37.0	30.3	25.7	22.3	19.6
2	258.	97.4	59.1	42.4	33.0	27.0	22.9	19.8	17 5
3	229.	86 7	52.6	37.7	29.4	24.0	20.4	17.6	15.6
4	204.	77.2	46 9	33.6	26.2	21.4	18.1	15.7	13.9
5	182.	68.8	41.7	29.9	23.3	19.1	16.1	14.0	12.4
6	162.	61.2	37.2	26.6	20.7	17.0	14.4	12.5	11.0
7	144.	54.5	33.1	23.7	18.5	15.1	12.8	11.1	9.8
8	128.	48.6	29.5	21.1	16.5	13.5	11.4	9.9	8.7
9	114.	43.2	26.3	18.8	14.7	12.0	10.2	8.8	7.8
10	102.	38.5	23.4	16.8	13.0	10.7	9.0	7.8	6.9
12	81.	30.5	18.5	13.3	10.3	8.5	7.2	6.2	5.5
14	64.	24.2	14.7	10.5	8.2	6.7	5.7	4.9	4.4
16	51.	19.3	11.7	8.4	6.5	5.3	4.5	3.9	3.4
18	40.	15.1	9.2	6.6	5.2	4.2	3.6	3.1	2.7
20	32.	12.1	7.3	5.3	4.1	3.4	2.8	2.5	2.2
22	25.3	9.6	5.8	4.2	3.2	2.7	2.2	1.9	1.7
Factor	1	3	5	7	9	11	13	15	17

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DIAMETER OF WIRES IN FLEXIBLES.

No. B. & S.	Number of Seven Wire Strands.					
	7	19	37	61	91	127
0000	65.7	39.9	28.6	22.3	18.2	15.4
000	58.5	35.5	25.5	19.8	16.2	13.7
00	52.1	31.6	22.7	17.7	14.5	12.2
0	46.4	28.2	20.2	15.7	12.9	10.9
1	41.3	25.1	18.0	14.0	11.5	9.7
2	36.9	22.3	16.0	12.5	10.2	8.6
3	32.7	19.9	14.2	11.1	9.1	7.7
4	29.1	17.7	12.7	9.9	8.1	6.9
5	26.0	15.8	11.3	8.8	7.2	6.1
6	23.1	14.0	10.1	7.8	6.4	5.4
7	20.6	12.5	9.0	7.0	5.7	4.8
8	18.3	11.1	8.0	6.2	5.1	4.3
9	16.3	9.9	7.1	5.5	4.5	.....
10	14.6	8.8	6.3	4.9	4.0	.....
12	11.5	7.0	5.0	3.9	3.2	..
14	9.2	5.6	4.0	3.1	2.5	.....
16	7.3	4.4	3.2	2.5	2.0	.....
18	5.8	3.5	2.5	1.9	1.6	.....
20	4.6	2.8	2.0	1.5	1.3	.....
22	3.6	2.2	1.6	1.2	1.0	.....
Factor.	9	15	21	27	33	39

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ALUMINUM WIRE.

The following constants at 20° C for hard-drawn aluminum wire are taken from Circular No. 31, of the Bureau of Standards, published in 1914.

1. The resistance of a wire one meter in length and of a uniform section of one square millimeter is .028 28 ohms.

2. The density is 2.70 grams per cubic centimeter.

3. The "constant mass" temperature co-efficient is .003 9 per degree Centigrade.

4. The coefficient of linear expansion is .000 023 1 per degree Centigrade.

The weight and resistance of aluminum wire and strands may be derived from the tables giving the weights and resistance of copper wires and strands, by multiplying by the following factors:

For weight .303 712
For resistance 1.640 24

For equal resistance, an aluminum wire or strand compares with copper as follows:

Weight of aluminum = weight of copper × .498 172
Diameter of aluminum = Diameter of copper × 1.28
Section of aluminum = section of copper x 1.64
1,640,000 C. M. of aluminum, and
1,000,000 C. M. of copper have the same resistance.

These factors are based on copper of 100% conductivity. Compared with hard-drawn copper of 97% conductivity, these factors become—

For weight, .483 227
For diameter, 1.26
For section, 1.59

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PROPERTIES OF ALUMINUM WIRE.

United States Units—Brown & Sharpe Gauge.

Numbers.	Diameter in mils.	Area in circular mils.	Weight in Pounds.		Resistance at 20° C—68° F.	
			1,000 feet.	Mile.	1,000 feet.	Mile.
0000	460.0	211 600.	194.5	1 027.	.0804	.424 8
000	409.6	167 806.	154.3	814.6	.1014	.534 7
00	364.8	133 077.	122.3	646.0	.1278	.674 1
0	324.9	105 535.	97.04	512.4	.1612	.851 3
1	289.3	83 692.7	76.93	406.4	.2032	1.073
2	257.6	66 371.3	61.02	322.2	.2564	1.353
3	229.4	52 634.8	48.38	255.5	.3231	1.706
4	204.3	41 741.3	38.39	202.6	.4076	2.152
5	181.9	33 102.4	30.43	160.7	.5139	2.713
6	162.0	26 251.4	24.13	127.4	.6481	3.422
7	144.3	20 818.3	19.14	101.0	.8172	4.314
8	128.5	16 509.7	15.18	80.15	1.030	5.441
9	114.4	13 092.8	12.04	63.57	1.299	6.859
10	101.9	10 383.0	9.546	50.39	1.638	8.651
11	90.74	8.234.11	7.569	39.97	2.067	10.91
12	80.81	6 529.95	6.004	31.71	2.605	13.76
13	71.96	5 178.48	4.762	25.14	3.285	17.34
14	64.08	4 106.72	3.775	19.94	4.142	21.86
15	57.07	3 256.78	2.994	15.81	5.223	27.57
16	50.82	2 582.74	2.374	12.54	6.587	34.77
17	45.26	2 048.21	1.883	9.944	8.306	43.86
18	40.30	1 624.30	1.493	7.884	10.47	55.29
19	35.89	1 288.13	1.184	6.253	13.21	69.73
20	31.96	1 021.53	.9391	4.960	16.65	87.93
21	28.46	810.114	.7447	3.933	21.00	110.9
22	25.35	642.450	.5907	3.119	26.47	139.8
23	22.57	509.486	.4683	2.473	33.40	176.3
24	20.10	404.041	.3714	1.961	42.10	222.3
25	17.90	320.419	.2946	1.555	53.09	280.3
26	15.94	254.104	.2336	1.233	66.94	353.5
27	14.20	201.513	.1853	.978	84.42	445.7
28	12.64	159.807	.1469	.776	106.5	562.1
29	11.26	126.728	.1165	.615	134.2	708.7
30	10.03	100.504	.0924	.488	169.3	893.8
31	8.928	79.7031	.0733	.387	213.4	1126.8
32	7.950	63.2075	.0581	.307	269.2	1421.1
33	7.080	50.1258	.0461	.243	339.4	1791.8
34	6.305	39.7516	.0365	.193	427.9	2259.6
35	5.615	31.5244	.0290	.153	539.6	2849.3
36	5.000	25.0000	.0230	.121	680.4	3592.8
37	4.453	19 8259	.0182	.096	858.0	4530.3
38	3.965	15.7227	.0145	.076	1082.	5712.8
39	3.531	12.4686	.0114	.060	1364.	7203.6
40	3.145	9.88807	.0091	.048	1721.	9083.6

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PROPERTIES OF ALUMINUM CONCENTRIC STRANDS.

C. M.	Diam. Inches.	Pounds.		Ohms 20° C.	
		1000 feet.	Mile.	1000 feet.	Mile.
3000	1.998	2 813	14 853	.005 79	.030 54
2750	1.914	2 579	13 616	.006 31	.033 31
2500	1.824	2 344	12 378	.006 94	.036 64
2250	1.729	2 110	11 140	.007 71	.040 71
2000	1.630	1 875	9 902	.008 68	.045 81
1950	1.610	1 829	9 655	.008 89	.046 98
1900	1.590	1 782	9 407	.009 14	.048 22
1850	1.569	1 735	9 160	.009 38	.049 52
1800	1.547	1 688	8 912	.009 64	.050 90
1750	1.526	1 641	8 665	.009 91	.052 36
1700	1.504	1 594	8 417	.010 20	.053 90
1650	1.482	1 547	8 170	.010 51	.055 52
1600	1.459	1 500	7 922	.010 84	.057 26
1550	1.436	1 454	7 674	.011 19	.059 11
1500	1.412	1 406	7 427	.011 56	.061 08
1450	1.388	1 360	7 179	.011 97	.063 18
1400	1.364	1 313	6 932	.012 40	.065 45
1350	1.340	1 266	6 684	.012 86	.067 86
1300	1.315	1 219	6 437	.013 35	.070 48
1250	1.289	1 172	6 189	.013 88	.073 29
1200	1.263	1 125	5 942	.014 47	.076 35
1150	1.236	1 078	5 694	.015 09	.079 67
1100	1.209	1 031	5 446	.015 78	.083 29
1050	1.181	985	5 199	.016 52	.087 26
1000	1.152	938	4 951	.017 35	.091 62
950	1.123	891	4 704	.018 27	.096 43
900	1.094	844	4 456	.019 27	.101 79
850	1.062	797	4 209	.020 42	.107 78
800	1.031	750	3 961	.021 68	.114 52
750	.998	703	3 713	.023 13	.122 15
700	.964	656	3 466	.024 78	.130 87
650	.929	610	3 218	.026 69	.140 95
600	.893	563	2 971	.028 92	.152 69
550	.855	516	2 723	.031 54	.166 57
500	.813	469	2 476	.034 71	.183 23
450	.772	422	2 228	.038 56	.203 59
400	.728	375	1 981	.043 38	.229 04
350	.681	328	1 733	.049 57	.261 77
300	.630	281	1 485	.057 83	.305 38
250	.575	234	1 238	.069 40	.366 46

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STEEL WIRE.

There are only a few metals that possess the physical properties that are necessary for wire drawing. Among these metals are gold, silver, copper, aluminum, and steel.

Steel, on account of its properties and price, is the most common material from which wire is drawn. Electrical conductivity is about the only property in which steel wire is excelled.

Steel is a composite substance consisting of an alloy of iron and carbide of iron, with more or less manganese, silicon, phosphorous, and sulphur.

The following tables are only approximately true for any one steel, but they are not far wrong for any steel. The diameters of the various sizes Brown & Sharpe Gauge and their area in circular mils are taken from page 76 to the nearest tenth of a mil. The diameter in millimeters and the area in square millimeters are taken from page 77. The dimensions and weights are computed from the following formulas:

Mils × .025 400 0508	=	Millimeters.
C. M. × .785 398 1634	=	Square Mils.
C. M. × .000 506 709 5059	=	Square Millimeters.
C. M. × .002 638 83	=	Pounds per 1000 feet.
C. M. × .013 933	=	Pounds per mile.
C. M. × .003 927	=	Kilograms per kilometer.

These constants correspond to the following weights at 20° C:

Cubic centimeter	=	7.75 grams.
Cubic inch	=	.279 988 pounds.
Cubic foot	=	483.82 pounds.

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PROPERTIES OF STEEL WIRE.

Roebling Wire Gauge.

Numbers.	Diameter.		Area in			Pounds per		Kg. per Km.
	Mils.	Millimeters.	C. M.	Square mils.	Square mm.	1000 feet.	Mile.	
000000	460	11.68	211 600	166 190	107.22	558.4	2 948	831.0
00000	430	10 92	184 900	145 220	93.69	487.9	2 576	726.1
0000	393	9.98	154 449	121 304	78.26	407.6	2 152	606.5
000	362	9.19	131 044	102 922	66.40	345.8	1 826	514.6
00	331	8.41	109 561	86 049	55.52	289.1	1 527	430.3
0	307	7.80	94 249	74 023	47.76	248.7	1 313	370.1
1	283	7.19	80 089	62 902	40.58	211.4	1 116	314.5
2	263	6.68	69 169	54 325	35.05	182.5	964	271.6
3	244	6.20	59 536	46 760	30.17	157.1	830	233.8
4	225	5.72	50 625	39 761	25.65	133.6	705	198.8
5	207	5.26	42 849	33 654	21.71	113.1	597	168.3
6	192	4.88	36 864	28 953	18.68	97.3	514	144.8
7	177	4.50	31 329	24 606	15.87	82.7	437	123.0
8	162	4.12	26 244	20 612	13.30	69.3	366	103.1
9	148	3.76	21 904	17 203	11.10	57.8	305	86.02
10	135	3.43	18 225	14 314	9.235	48.1	254	71.57
11	120	3.05	14 400	11 310	7.297	38 0	201	56.55
12	105	2.67	11 025	8 659	5.586	29 1	154	43.30
13	92	2.34	8 464	6 648	4.289	22 3	118	33.24
14	80	2.03	6 400	5 027	3.243	16.9	89.2	25.13
15	72	1.83	5 184	4 072	2.627	13.7	72.2	20.36
16	63	1.60	3 969	3 117	2.011	10 5	55.3	15.59
17	54	1.37	2 916	2 290	1 478	7.70	40.6	11.45
18	47	1.19	2 209	1 735	1.119	5.83	30.8	8.675
19	41	1.04	1 681	1 320	.851 8	4.44	23.4	6.602
20	35	.889	1 225	962	.620 7	3.23	17.1	4.811
21	32	.813	1 024	804	.518 9	2.70	14.3	4.021
22	28	.711	784	616	.397 3	2.07	10.9	3.079
23	25	.635	625	491	.316 7	1.65	8.71	2.454
24	23	.584	529	415	.268 0	1.40	7.37	2.077
25	20	.508	400	314	.202 7	1.06	5.57	1.571
26	18	.457	324	254	.164 2	.855	4.51	1.272
27	17	.432	289	227	.146 4	.763	4.03	1.135
28	16	.406	256	201.1	.129 7	.676	3.57	1.005
29	15	.381	225	176.7	.114 0	.594	3.14	.884
30	14	.356	196	153.9	.099 3	.517	2.73	.770
31	13.5	.343	182.25	143.1	.092 4	.481	2.54	.716
32	13	.330	169.	132.7	.085 6	.446	2.36	.664
33	11	.279	121.	95.0	.061 3	.319	1.69	.475
34	10	.254	100.	78.5	.050 7	.264	1.39	.393
35	9.5	.241	90.25	70.9	.045 7	.238	1.26	.354
36	9	.229	81.	63.6	.041 0	.214	1.13	.318
37	8.5	.216	72.25	56.7	.036 6	.191	1.01	.284
38	8.0	.203	64.	50.3	.032 4	.169	.89	.251
39	7.5	.191	56.25	44.2	.028 5	.148	.78	.221
40	7.0	.178	49.	38.5	.024 8	.129	.68	.192

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PROPERTIES OF STEEL WIRE.

Brown and Sharpe Gauge.

Numbers.	Diameter.		Area in			Pounds per		Kg. per Km.
	Mils.	Millimeters.	C. M.	Square mils.	Square mm.	1000 feet.	Mile.	
0000	460.0	11.68	211 600	166 190	107.22	558.4	2 948	831.0
000	409.6	10.40	167 806	131 795	85.03	442.8	2 338	659.0
00	364.8	9.27	133 077	104 518	67.43	351.2	1 854	522.6
0	324.9	8.25	105 535	82 887	53.48	278.5	1 470	414.5
1	289.3	7.35	83 693	65 732	42.41	220.9	1 166	328.7
2	257.6	6.54	66 371	52 128	33.63	175.1	925	260.7
3	229.4	5.83	52 635	41 339	26.67	149.5	789	222.4
4	204.3	5.19	41 741	32 784	21.15	110.2	582	163.9
5	181.9	4.62	33 102	25 999	16.77	87.4	461	130.0
6	162.0	4.12	26 251	20 618	13.31	69.3	366	103.1
7	144.3	3.67	20 818	16 351	10.55	54.9	290	81.76
8	128.5	3.26	16 510	12 967	8.37	43.6	230	64.84
9	114.4	2.91	13 093	10 283	6.63	34.6	182	51.42
10	101.9	2.59	10 383	8 155	5.26	27.4	145	40.78
11	90.7	2.30	8 234	6 467	4.17	21.7	115	32.34
12	80.8	2.05	6 530	5 129	3.31	17.2	91.0	25.64
13	72.0	1.83	5 178	4 067	2.62	13.7	72.1	20.34
14	64.1	1.63	4 107	3 225	2.08	10 8	57.2	16.13
15	57.1	1.45	3 257	2 558	1.65	8.60	45.4	12.79
16	50.8	1.29	2 583	2 028	1.31	6.82	36.0	10.14
17	45.3	1.15	2 048	1 609	1.04	5.40	28.5	8.043
18	40.3	1.02	1 624	1 276	.823	4.29	22.6	6.378
19	35.9	.912	1 288	1 012	.653	3.40	17.9	5.058
20	32.0	.812	1 022	802	.518	2.70	14.2	4.014
21	28.5	.723	810	636	.411	2.14	11.3	3.181
22	25.3	.644	642	505	.326	1.69	8.95	2.521
23	22.6	.573	509	400	.258	1.34	7.09	2.000
24	20.1	.511	404	317	.205	1.07	5.63	1.587
25	17.9	.455	320	252	.162	.844	4.46	1.257
26	15.9	.405	254	200	.129	.670	3.54	.998
27	14.2	.361	201.5	158.3	.102	.532	2.81	.791
28	12.6	.321	159.8	125.5	.081	.422	2.23	.628
29	11.3	.286	126.7	99.5	.064	.334	1.77	.498
30	10.0	.255	100.5	78.9	.051	.265	1.40	.395
31	8.9	.227	79.7	62.6	.040	.210	1.11	.313
32	8.0	.202	63.2	49.6	.032	.167	.88	.248
33	7.1	.180	50.1	39.4	.025	.132	.70	.197
34	6.3	.160	39.8	31.2	.020	.105	.55	.156
35	5.6	.143	31.5	24.8	.016	.083	.44	.124
36	5.0	.127	25.0	19.6	.013	.066	.35	.098
37	4.5	.113	19.8	15.6	.010	.052	.28	.078
38	4.0	.101	15.7	12.3	.008	.041	.22	.062
39	3.5	.090	12.5	9.8	.006	.033	.17	.049
40	3.1	.080	9.9	7.8	.005	.026	.14	.039

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BRONZE WIRE.

Bronze wire has two and one-half times the resistance of copper wire, but it is from 36% stronger in the larger sizes to 75% stronger in the finer sizes than copper. The resistance of E. B. B. is five and one-third times copper.

Bronze is stronger than copper and a better conductor than steel. It is not as easily corroded as steel, and is especially adapted to places where bare wire is used and corrosion is common. Along the sea shore, the salt, and in cities, the products of burned sulphur in the air attack all metals.

It may be used as trolley wire in either the usual round section or in the standard grooved form. It is adapted for span wires and for telegraph and telephone lines where greater strength than copper is necessary, and greater conductivity or greater resistance to corrosion than steel affords is desirable. The formulas for calculating resistances and weights are as follows:

$$\text{Ohms per 1000 feet} = \frac{25\,928.}{d^2}$$

$$\text{Ohms per mile} = \frac{136\,900.}{d^2}$$

$$\text{Ohms per kilometer} = \frac{850\,655.}{d^2}$$

$$\text{Pounds per 1000 feet} = .003\,012\ d^2$$

$$\text{Pounds per mile} = .015\,902\,6\ d^2$$

$$\text{Kilogram per kilometer} = .004\,482\,13\ d^2$$

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BRONZE WIRE, 20° C.

B. & S. Gauge.	Diam. in Mils.	Pounds per		Ohms per		Breaking weight.
		1000 feet.	Mile.	1000 feet.	Mile.	
0000	460	637	3365	.123	.647	11 467
000	410	505	2669	.155	.816	9 120
00	365	407	2116	.195	1.028	7 381
0	325	318	1678	.246	1.298	6 285
1	289	252	1331	.310	1.635	5 127
2	258	200	1055	.391	2.063	4 170
3	229	159	837	.493	2.600	3 348
4	204	126	664	.621	3.280	2 662
5	182	100	526	.783	4.135	2 114
6	162	79	417	.988	5.215	1 682
7	144	63	331	1.245	6.575	1 346
8	128	50	263	1.570	8.293	1 072
9	114	39	208	1.980	10.455	853
10	102	31	165	2.497	13.185	683
11	91	25	131	3.149	16.625	543
12	81	20	104	3.971	20.965	436
13	72	15.6	82	5.007	26.425	350
14	65	12.4	65	6.313	33.325	281
15	57	9.8	52	7.961	42.025	225
16	51	7.8	41	10.040	53.000	181
17	45	6.2	33	12.660	66.850	145
18	40	4.9	26	15.963	84.275	116

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Properties of Metals.

If the following properties of a metal are known, its resistance and weight may be expressed in many different units:

Ohms per meter square millimeter.
Constant mass temperature coefficient.
Grams per cubic centimeter.
Coefficient of linear expansion.

Properties of Metals at 20° C.

Metal.	Ohms per meter sq. mm.	Grams per cubic centimeter.	Temperature coefficient.	Coefficient of linear expansion.
Aluminum	.028 28	2.70	.003 90	.000 023
Antimony	.382 0	6 63	.003 61	.000 011
Bismuth	1.195 3	9.68	.003 99	.000 016
Cadmium	.100 86	8 55	.003 87	
Copper, soft	.017 241	8.89	.003 93	.000 017
" hard	.017 719	8.89	.003 82	.000 017
Gold	.023 57	19.22	.003 51	.000 014
E. B. B.	.108 47	7.75	.004 69	.000 012
B. B.	.123 97	7.77	.004 09	.000 012
Steel	.146 13	7.79	.003 46	.000 012
Lead	.209 0	11.34	.003 80	.000 029
Lead, 1% tin	.211 0	11.28		
Lead, 2% tin	.213 9	11.22		
Lead, 3% tin	.216 8	11.16		
Lead, ½% Sb.	.210 0	11.28		
Lead, ¾% Sb.	.205 0	11.22		
Lead, 1% Sb.	.200 0	11.16		
Mercury	.954 47	13.55	.000 72	.000 060
Nickel	.077 92	8.65	.005 50	.000 013
Platinum	.117 18	21.50	.003 42	.000 009
Silver	.015 85	10.41	.003 70	.000 019
Tin	.142 0	7.30	.004 13	.000 022
Zinc	.062 18	6.92	.003 78	.000 029

Sb. = Antimony.

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Resistance Based on Section.

The following table gives factors for changin ohms per meter square millimeter into ohms for oth units of length and section. To change to ohn per foot circular mil, multiply by 601.529. microhms per centimeter cube are given and ohn per 1000 feet square inch are wanted, divide by 1(and multiply by .47244:

Length.	Section.	Ohms.
Meter	Square millimeter	1.
Kilometer	" "	1 000.
Foot	" "	.304 800
1000 feet	" "	304.800 609
Mile	" "	1 609.347 219
Meter	Circular "	1.273 239 545
Kilometer	" "	1 273.239 545
Foot	" "	.388 084 1894
1000 feet	" "	388.084 189 4
Mile	" "	2 049.084 521
Meter	Square mil	1 549.996 9
Kilometer	" "	1 549 996.9
Foot	" "	472.44
1000 feet	" "	472 440.
Mile	" "	2 494 483.2
Meter	Circular mil	1 973.517 347
Kilometer	" "	1 973 517.347
Foot	" "	601.529 290 4
1000 feet	" "	601 529.290 4
Mile	" "	3 176 074.654
Meter	Square inch	.001 549 9969
Kilometer	" "	1.549 996 9
Foot	" "	.000 472 44
1000 feet	" "	.472 44
Mile	" "	2.494 483 2

Microhms per centimeter cube, 100.
Microhms per inch cube 39.37

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Resistance Based on Weight.

The product of the ohms per meter square millimeter and the grams per cubic centimeter, gives the ohms per meter gram.

The following table gives factors for changing ohms per meter gram into ohms for other lengths and weights.

To change to ohms per mile pound, multiply by 5709.97.

Length.	Weight.	Ohms.
Meter	Gram	1.
Kilometer	"	1 000 000.
Foot	"	.092 903 411 61
1000 feet	"	92 903.411 61
Mile	"	2 589 998.471
Meter	Kilogram	.001
Kilometer	"	1 000.
Foot	"	.000 092 903 4116
1000 feet	"	92.903 411 61
Mile	"	2 589.998 471
Meter	Grain	15.432 356 39
Kilometer	"	15 432 356.39
Foot	"	1.433 718 558
1000 feet	"	1 433 718.558
Mile	"	39 969 779.44
Meter	Pound	.002 204 622 341
Kilometer	"	2 204.622 341
Foot	"	.000 204 816 9368
1000 feet	"	204.816 936 8
Mile	"	5 709.968 492

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Weight.

The specific gravity of a substance is the ratio of its weight to the weight of an equal volume of water. The more definite way of expressing the density of a substance is to give the weight of a definite volume of the substance at a certain temperature. Copper, for example, at 20° C weighs 8.89 grams per cubic centimeter, and has a coefficient of linear expansion of .000 017 per degree C. At 0° C the volume of a cubic centimeter of copper at 20° C is $.999\,66^3$ cubic centimeters, and the weight per cubic centimeter at 0° will be 8.89 grams ÷ $.999\,66^3$ or 8.899 073 969 grams. A cubic centimeter of water at 4° C weighs .999 973 grams, hence the specific gravity at $\frac{0°}{4°}$ C, of copper will be 8.899 073 969 ÷ .999 973 or 8.8993.

The specific gravity at $\frac{0°}{4°}$ C of a substance multiplied by .999 973 equals the weight of a cubic centimeter at 0° in grams, and by using the temperature coefficient of linear expansion the weight of a cubic centimeter at 20° may be found.

For copper—

$$\frac{8.8993 \times .999\,973}{1.000\,34^3} = 8.89.$$

The following table gives factors for changing grams per cubic centimeter to weights for other units of length and section:

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WEIGHTS.

Length.	Section.	Grams.	Pounds.
Meter	Sq. mm.	1.	.002 204 622 341
Kilometer	" "	1 000.	2.204 622 341
Foot	" "	.304 800 6096	.000 671 970 233 6
1000 feet	" "	304.800 609 6	.671 970 233 6
Mile	" "	1 609.347 219	3.548 002 833
Meter	Cir. mm.	.785 398 1634	.001 731 506 338
Kilometer	" "	785.398 163 4	1.731 506 338
Foot	" "	.239 389 8390	.000 527 764 1873
1000 feet	" "	239.389 839 0	.527 764 187 3
Mile	" "	1 263.978 350	2.786 594 909
Meter	Sq. mil.	.000 645 162 5	.000 001 422 339 839
Kilometer	" "	.645 162 580 6	.001 422 339 839
Foot	" "	.000 196 645 947	.000 000 433 530
1000 feet	" "	.196 645 947 9	.000 433 530 050
Mile	" "	1.038 290 605	.002 289 038 664
Meter	Cir. mil.	.000 506 709 505	.000 001 117 10309
Kilometer	" "	.506 709 505 9	.001 117 103 097
Foot	" "	.000 154 445	.000 000 340 493
1000 feet	" "	.154 445 366 3	.000 340 493 7051
Mile	" "	.815 471 534 1	.001 797 806 763
Meter	Sq. In.	645.162 580 6	1.422 339 839
Kilometer	" "	645 162.580 6	1 422.339 839
Foot	" "	196.645 947 9	.433 530 050
1000 feet	" "	196 645.947 9	433.530 050
Mile	" "	1 038 290.604 9	2 289.038 664
Foot	Sq. foot.	28 317.016 49	62.428 327 21
Inch	Sq. inch.	16.387 162 32	.036 127 504 16
Cm.	Sq. cm.	1.	.002 204 622 341

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TABLES OF WEIGHTS AND RESISTANCES.

In order to compute tables of the weight and resistance of wires it is best to work from diameters, expressed either in mils or millimeters. To find the conductivity of a wire it is better to work from weight than diameter. The diameter of a wire may be measured with a micrometer to one part in five hundred, but a sample of wire may be weighed to one in a million. Where the diameter is unknown the method by weight should always be used, but in calculating a table the diameter is assumed, not determined, and there is no reason why weights and resistances should not be determined directly from area depending on diameter. The area most easily derived from the diameter is an area expressed in circular units, either circular mils or circular millimeters, equal to the square of the diameter in mils or millimeters.

The formulas for weight, when the diameter in mils is given, are,

Pounds per 1000 feet $= d^2 \times .000\,340\,493\,705$
Pounds per mile $= d^2 \times .001\,797\,806\,76$
Kilograms per kilometer $= d^2 \times .506\,709\,506$

When the diameter is in millimeters—

Pounds per 1000 feet $= d^2 \times .527\,764\,187$
Pounds per mile $= d^2 \times 2.786\,594\,91$
Kilograms per kilometer $= d^2 \times 785.398\,163$

The above factors are for a weight of one gram per cubic centimeter and should be multiplied by the number representing the weight in grams of a cubic centimeter of the metal. For copper this is 8.89, and for aluminum 2.7.

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The formulas for resistance when the diameter in mils is given are—

Ohms per 1000 feet $= 601\,529.290 \div d^2$
Ohms per mile $= 3\,176\,074.65 \div d^2$
Ohms per kilometer $= 1\,973\,517.35 \div d^2$

When the diameter is in millimeters—

Ohms per 1000 feet $= 388.084\,189 \div d^2$
Ohms per mile $= 2\,049.084\,52 \div d^2$
Ohms per kilometer $= 1\,273.239\,55 \div d^2$

The above factors are for a resistance of one ohm per meter square millimeter, and should be multiplied by the number representing the ohms per meter square millimeter for the metal.

For copper this is .017 241 379 3

For strands where the area is given in circular mils use that area in circular mils instead of d^2.

The formulas given above for weight and resistance are for solid wires. In order to get formulas for strands or for ropes the constants given for solid wires are multiplied by 1.02 for strands and by 1.04 for ropes. The final constant may be taken to the nearest six significant figures.

Resistance may be calculated from weight, by means of the following formulas:

Ohms per 1000 feet $= 204.817 \div$ pounds per 1000 ft.
Ohms per mile $= 5709.968 \div$ pounds per mile.
Ohms per kilometer $= 1000.000 \div$ Kg. per Km.

The above factors are for a resistance of one ohm per meter gram and should be multiplied by the number representing the ohms per meter gram for the metal.

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ELECTRIC TRANSMISSION OF POWER.

In its broader sense, this includes all electric transmission for light, power, and signals. Water power is one source of supply for electricity. The power houses at Niagara Falls utilize the power of Niagara River, and this power is transmitted as far east as Syracuse, a distance of about one hundred and fifty miles. In the mountains east of the coast states are located power plants connected with the various cities of the coast by long transmission lines. A comparatively large amount of power is transmitted over these lines at voltages from 45,000 to 100,000. Sometimes wooden poles, but more frequently iron towers, are used to support the wires. The spans may be divided into three classes—

Long spans.....500 feet to 800 feet.
Medium spans.....300 feet to 500 feet.
Short spans .....less than 300 feet.

The wire transmission line may include power wires, telephone wires, and a ground wire. The power wires may be copper, aluminum, or steel.

The length of span that may safely be used with a wire of a given metal depends on the way the wire is strung and also on the climatic conditions. It is usual to assume that the wire shall support a load equal to one-half inch of ice and at the same time a horizontal wind pressure of eight pounds to the projected square foot, at a temperature of 0° F.

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Without the ice load one size wire will do as well as another. A No. 20 copper wire in the summer time will sustain itself over as large a span as a No. 4, but when the ice load is taken into consideration a larger wire is necessary in order to give a span with a reasonable sag.

Steel is not economical as a material for transmission lines except in those cases where a copper wire considerably larger than is necessary to carry the electrical load has to be used in order to support, theoretically at least, this ice load. The product of the mile ohm and the price per pound of wires gives a measure of their cost taking into effect their efficiency as conductors.

Material.	Mile ohm.	Price.	Product.
Soft copper	875.20	30.00	262.56
Hard copper	902.3	29.10	262.57
Aluminum	437	60.08	262.55
E. B. B.	4800	5.47	262.56

The table shows that the price of aluminum should be twice that of copper, and the price of E. B. B. steel 10% less than one-fifth the price of copper, in order to make the cost per mile for conductors the same with the same resistance per mile. The price of steel is usually too great to make it an economical conductor except where the load is small. A very complete article on this subject of the use of steel for power circuits is given in the Electrical World and Engineer of April 8, 1916.

For hard drawn copper wire good practice would indicate that up to 204 mils the wire might be solid, although some large lines use a stranded

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wire as small as 162 mils. For sizes heavier than 204 mils a stranded wire should be used.

Telephone wires may be either hard drawn copper or galvanized steel. The copper runs from 165 mils to 64 mils, and the steel from 238 to 83 mils. The ground wire carried on the top of the poles is usually a $^3/_8''$ galvanized Siemens-Martin seven-wire strand.

In the transmission of power from a local power house in a city for light or for railway work, the voltage is usually 2300, 6600, or 13200. The two higher voltages are usually transmitted through underground cables. The more common voltage, especially for the smaller cities, is 2300 transmitted over pole lines, usually through weatherproof wire. It is common practice to use soft copper for this work, but there are a great many advantages to be derived by the use of hard copper, especially for the smaller sizes. Conductors No. 4 B. & S. and smaller may be solid wires, while No. 3 to No. 0000 may be hard drawn strand, and above No. 0000 soft stranded copper would undoubtedly be used on account of the greater ease in handling.

Telegraph and Telephone Lines.

In the larger cities distribution is usually by underground cables, but in the smaller cities and from one city to another the distribution is over pole lines. In the cities weatherproof wires are sometimes used but not always, but from city to city bare wire is the practice. The line materials are hard drawn copper and the three grades of galvanized steel—E. B. B., B. B., and Steel. For a long

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distance line, where conductivity is an essential part, copper is the most economical material. For a comparatively short line some one of the three kinds of galvanized steel wire will be found economical.

The sizes of hard drawn copper wire run from 165 mils between New York and Chicago to 64 mils., and for steel wire from 238 mils to 83 mils.

HARD COPPER WIRE.

Wire bars turned out by the smelter are about 4″ square, and from 48″ to 96″ long, weighing from 200 pounds to 400 pounds. These bars are heated to a red heat in a furnace and are then passed, while still hot, successively through rolls until they are reduced to rods having a diameter from one inch to one-quarter of an inch.

The rods are cleaned and drawn down to various sizes. This drawing increases the strength of the copper, but decreases its conductivity and stretch. From the specifications given on page 80, soft wire has a resistance per meter gram of not more than .156 14 ohms, and tensile strength of not more than 36000 pounds per square inch; while hard wire has a resistance per meter gram of not more than .159 40 ohms, and a tensile strength of not less than 67000 pounds per square inch. Soft copper wire is frequently found with a resistance of not over .153 28 ohms per meter gram and a strength of not over 32000 pounds per square inch. Between the limits of the softest and the hardest copper, there are any number of

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stages. After the copper is drawn, its hardness depends on the amount and the kind of drawing. In a general way, increased drawing increases the hardness. All wire after the drawing is hard. The term "hard drawn" is not accurate, although it is a term in common use to designate hard copper. When soft copper is wanted, the hard copper is annealed by heating it to a red heat. The softness of the copper depends on this annealing. The natural hard drawn copper is the copper that is drawn from a certain size rod, say $\frac{3}{8}''$, to a No. 10, No. 12, or No. 14 wire as the case may be. Its hardness varies with the size. The grade of copper known as Medium Hard Drawn is part way between hard copper and soft copper, and can be produced in a very irregular way by only part annealing hard copper. The true way is to anneal on the way down at just such a stage in the wire-drawing as to make the further drawing of the annealed wire such as to produce the desired medium hardness. Medium hard wire is more expensive than either soft wire or hard wire.

The table is calculated from the data given on pages 80 and 82.

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HARD COPPER WIRE—20° C.

B. & S. gauge.	Diameter in mils.	Pounds per		Hard.			Medium Hard.			
				Ohms per		Breaking weight.	Ohms per		Breaking weight.	
		1000 feet.	Mile.	1000 feet.	Mile.		1000 feet.	Mile.	Minimum.	Maximum.
0000	460	641	3382	.050	.266	8143	.050	.265	6980	8143
000	410	508	2682	.064	.336	6722	.063	.334	5668	6590
00	365	403	2127	.080	.424	5519	.080	.421	4599	5330
0	325	320	1687	.101	.534	4517	.101	.531	3730	4310
1	289	253	1338	.129	.680	3688	.128	.677	3024	3484
2	258	201	1061	.165	864	3003	163	.859	2450	2815
3	229	159	841	.205	1.082	2439	.204	1.076	1984	2274
4	204	126	667	.258	1.364	1970	.257	1.357	1584	1814
5	182	100	529	.326	1.720	1591	.324	1.711	1264	1446
6	162	79	420	.411	2.169	1280	.409	2.158	1010	1155
7	144	63	333	.518	2.735	1030	.515	2.721	807	921
8	128	50	264	.653	3.449	826	.650	3.431	644	735
9	114	40	209	.824	4.349	661	.820	4.327	514	586
10	102	31	166	1.039	5.484	529	1.033	5.456	410	468
11	91	25	132	1.310	6.916	423	1.303	6.880	328	373
12	81	20	104	1.652	8.721	337	1.643	8.675	262	297
13	72	15.7	83	2.083	10.997	268	2.072	10.939	209	237
14	64	12.4	66	2.626	13.866	214	2.613	13.794	167	189
15	57	9.9	52	3.312	17.485	170	3.294	17.394	133	151
16	51	7.8	41	4.176	22.048	135	4.154	21.934	106	120
17	45	6.2	33	5.266	27.802	107	5.238	27.658	85	96
18	40	4.9	26	6.640	35.058	85	6.605	34.876	68	77

TELEPHONE AND TELEGRAPH WIRE.

Galvanized wire varies between wide limits in its electrical and physical properties. There are three grades used in electrical work known in the trade as Extra Best Best, Best Best, and Steel, abbreviated to E. B. B., B. B., and Steel. The electrical properties of these wires are expressed by the product of the weight per mile and the resistance per mile. This product is a constant quantity at a given temperature for any size of wire, provided the electrical properties of the material are the same.

	4 B. W. G.	14 B. W. G.
Pounds per mile	787	96
Ohms per mile	5.972	48.958
Product	4700	4700

This product may be called the mile ohm or the mile pound. The mile ohm is the weight in pounds of a wire one mile long, having a resistance of one ohm. The mile pound is the resistance in ohms of a mile of wire weighing one pound.

If a wire 52.8 feet long has a resistance of .0597 ohms and weighs 7.87 pounds, the mile ohm will be,

$$\frac{(7.87 \times 5280) \times (.0597 \times 5280)}{52.8 \times 52.8} \text{ or } 4700.$$

The temperature coefficient of steel wire per degree C from 20° is equal to 22.5 divided by the pounds per mile ohm. The adder is the constant-mass temperature coefficient less twice the coefficient of linear expansion, multiplied by the mile ohm.

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The following table illustrates:

Mile ohm.	Temperature coefficients.	Factor.	Adder.
4 500	.005 00	.004 976	2.239
5 000	.004 50	.004 476	2.238
7 500	.003 00	.002 976	2.232
10 000	.002 25	.002 226	2.226

If we take the constant adder as 2.24 we will be correct to within less than .01 of a pound in a mile ohm of about 5000 pounds.

The methods of obtaining the figures in the above table are illustrated herewith.

$$22.5 \div 4500 = .005$$
$$.005 - (.000\,012 \times 2) = .004\,976$$
$$4500 \times .004\,976 = 2239$$

A more detailed account of this matter will be found on page 71.

If a wire 52.8 feet long at 15° C weighs 9 pounds and has a resistance of .06 ohms, the mile ohm at 15° is $9 \times .06 \times 10\,000$ or 5400. To find the mile ohm at 20° add five times 2.24 or 11.2 to 5400, making the mile ohm of this wire at 20° C, 5411.2.

The electrical constants for the three grades of galvanized telegraph wire are given herewith:

	E. B. B.	B. B.	Steel.
Mile ohm, minimum	4600	5000	6000
Mile ohm, maximum	5000	6000	7000
Mile ohm, average	4850	5800	6750
Temp. coefficient	.00464	.00388	.00333

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This table is the one commonly used to give the properties of Galvanized Telegraph and Telephone wires.

Double Galvanized Telegraph and Telephone Wire.

Birmingham Wire Gauge.

Number.	Diameter in mils.	Pounds per mile.	Miles per bundle.	Approximate breaking strain in pounds.			Ohms per mile 68° F.		
				E. B. B.	B. B.	Steel.	E. B. B.	B. B.	Steel.
4	238	811	1/4	2 028	2 271	2 433	5.98	7.15	8.32
6	203	590	1/3	1 475	1 652	1 770	8.22	9.83	11.44
8	165	390	1/2	975	1 092	1 170	12.43	14.87	17.31
9	148	314	1/2	785	879	942	15.44	18.47	21.50
10	134	258	1/2	645	722	774	18.79	22.48	26.16
11	120	206	1/2	515	577	618	23.54	28.16	32.77
12	109	170	1/2	425	476	510	28.52	34.12	39.71
14	83	99	1/2	247	277	297	48.98	58.59	68.18

SPECIFICATIONS FOR DOUBLE GALVANIZED TELEGRAPH AND TELEPHONE WIRE.

Testing Facilities.

The manufacturer shall provide suitable facilities for making all necessary tests.

Finish.

The wire shall be cylindrical in form and free from scales, inequalities, flaws, splints, and other imperfections.

The finish of the wire shall be in accordance with the best commercial practice.

Each coil shall be warranted not to contain any weld, joint, or splice in the rod before it is drawn.

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Galvanizing.

The galvanizing shall consist of a continuous coating of pure zinc of practically uniform thickness, and so applied that it adheres firmly to the surface of the wire. No. 14 B. W. G. and coarser sizes of wire shall be capable of withstanding the following test:

Testing Solution.

A standard solution shall be prepared by selecting from commercial sulphate of copper crystals, those which are clean and have a clear blue color, and dissolving them in water. The solution shall be allowed to stand for at least twelve hours with occasional stirring. Some undissolved crystals should remain at the bottom of the vessel at the end of this time. The solution shall be neutralized by the addition of an excess of cupric oxide. The neutralized solution shall then be filtered before using. A saturated solution of sulphate of copper thus prepared should have a specific gravity of 1.186 at a temperature of 65 degrees F.

Method of Testing.

Samples of wire previously cleaned with gasoline or benzine shall be immersed, to a distance of at least four inches, in a glass vessel containing not less than one pint of the standard solution and allowed to remain for one minute. They shall then be removed, washed in clear water, and wiped dry with soft cotton cloth or waste. This process shall be repeated three times, making four immersions

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in all. For No. 14 B. W. G. wire the fourth immersion shall be of one-half minute duration instead of one minute.

The temperature of the solution during the test shall be from 62 degrees F to 68 degrees F.

Not more than seven samples of wire shall be immersed at one time, and no solution shall be used for more than one set of four immersions.

If a bright copper deposit appears on the steel after the fourth immersion, thus indicating that the wire is exposed, the galvanizing of the lot of wire represented by the samples shall be considered faulty. Copper deposits on zinc or within one inch of the cut end shall not be considered causes for rejection.

TRANSMISSION STRAND.

It is sometimes desirable to use B. B. or E. B. B. Galvanized Telegraph Wire for transmission work in larger sizes than No. 4 B. W. G. The obvious thing is to make galvanized wires into strands of seven wires, nineteen wires, or into ropes of seven strands, each containing seven wires, depending on the size wanted. The following table gives the properties of such strands.

The weight and resistance is made 2% more than the weight and resistance of all the wires, and the breaking strength 90% of the breaking strength of all the wires, for seven and nineteen wire strands, and 85% for 7 x 7 rope.

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TRANSMISSION STRAND.

1000 FEET, 68°.

Number wires.	Size B. W. G.	Outside diameter.	Pounds 1000 feet.	Extra Best Best.			Best Best.	
				Ohms.	Strength.	Copper.	Ohms.	Strength.
7	4	.714	1 097	.1650	15 300	2	.1973	16 900
7	6	.609	798	.2246	11 200	4	.2713	12 300
7	8	.495	527	.3430	7 400	5	.4104	8 100
7	9	.444	425	.4261	5 900	6	.5097	6 500
7	10	.402	349	.5188	4 900	7	.6204	5 400
7	11	.360	279	.6496	3 900	8	.7769	4 300
7	12	.327	230	.7874	3 200	9	.9416	3 500
7	14	.249	134	1.3523	1 900	11	1.6167	2 100
19	4	1.190	2 977	.0608	41 600	000	.0727	45 800
19	6	1.015	2 166	.0828	30 300	00	.0999	33 300
19	8	.825	1 431	.1264	20 000	1	.1512	22 000
19	9	.740	1 153	.1570	16 100	2	.1878	17 700
19	10	.670	947	.1911	13 200	3	.2286	14 600
19	11	.600	756	.2393	10 600	4	.2862	11 600
19	12	.545	624	.2901	8 700	5	.3469	9 600
10	14	.415	363	.4982	5 100	7	.5956	5 600
7 x 7	8	1.485	3 764	.0500	48 700	0000	.0598	53 600
7 x 7	9	1.332	3 031	.0621	39 200	000	.0742	43 100
7 x 7	10	1.206	2 490	.0756	32 200	00	.0904	35 400
7 x 7	11	1.080	1 988	.0946	25 700	0	.1132	28 300
7 x 7	12	.981	1 641	.1147	21 200	1	.1372	23 400
7 x 7	14	.747	955	.1970	12 400	3	.2355	13 600

In the column headed "copper" are given the sizes B. & S. solid copper wire having a resistance nearest to that of the galvanized strand. For B. B. the size of copper is one less than E. B. B. 7 x 4 B. W. G. B. B. has about the same resistance as No. 3 B. & S. solid copper wire.

Galvanized strands may be used for electrical transmission. The resistance depends on the kind, the higher the breaking strength the higher the resistance. The resistance per 1000 feet of galvanized strand is equal to the following constants divided by the weight per 1000 feet.

Kind of strand.	Constants.
Siemens-Martin	261.1
High Strength	298.4
Extra High Strength	335.7

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GALVANIZED STRAND.

Galvanized strand is usually composed of seven or nineteen wires, but sometimes of thirty-seven or sixty-one. The wires may have a strength anywhere from 60,000 pounds to 350,000 pounds per square inch. The purpose for which the strand is intended determines its strength. It is always a good investment to buy double galvanized wire, owing to its longer life.

The breaking weight of a galvanized strand is about 90% of the sum of the breaking weight of the individual wires. The breaking weight of the individual wires depends on their treatment and drawing. As a general rule the smaller the wire the higher the breaking strain per square inch of metal. We, therefore, expect the smaller sizes of galvanized strand to have a higher breaking strain in proportion than the larger sizes. Any statement as to the breaking strain of a class of galvanized strands must be approximate, owing to this diversity of results found among the different sizes.

Galvanized strands have many uses, among which are the following:

For guying smoke stacks,

For carrying telephone cables on a pole line,

For carrying trolley wire in catenary construction,

For protecting transmission lines from lightning when used as a ground wire,

For long spans in transmission lines.

In the following brief description of the various qualities of strand, the uses to which the various kinds may be put are given under their proper heading.

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Ordinary Galvanized Strand.

The breaking weight of this strand is from fifteen to twenty times its weight per 1000 feet. This strand is used for guying stacks, for signal strand, for trolley span wire, and other purposes where no great flexibility is required, and where a strand of moderate strength will meet all requirements.

Siemens-Martin Strand.

This strand has a breaking weight of from twenty to thirty times its weight per 1000 feet. This strand is composed of very soft pliable wire, but of considerably higher strength than the ordinary. Owing to these qualities it is largely used for messenger wire to carry telephone cables. Ordinary practice is to use a galvanized strand to carry cables of the following weights per 1000 feet for spans of 150 feet or less:

1/2″	galvanized strand	.....lbs.	per	1000 ft.	cable.
7/16″	"	.....	"	"	"
3/8″	"	.....	"	"	"
5/16″	"	.....	"	"	"

For supporting trolley wire, catenary construction, up to 150 feet spans, 3/8″ or 7/16″ Siemens-Martin Strand is used. For ground wires on high tension transmission lines 3/8″ Siemens-Martin Strand is used.

High Strength Strand.

The breaking weight of this strand is over thirty times its weight per 1000 feet. It is used where a stronger strand than Siemens-Martin is required. It is consequently stiffer and more difficult to handle. When once in place it is very efficient.

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Extra High Strength Strand.

The breaking weight of this strand is over fifty times its weight per 1000 feet. What has been said about High Strength Strand is true of this strand, but in a more pronounced degree.

GALVANIZED STRANDS.

Diameter of strand.	Wires.		Pounds per 1000 feet.	Breaking weight in pounds.			
	Number.	Mils.		a	b	c	d
1¾	61	194	6 210	89 000	149 000	227 000	334 000
1⅝	61	181	5 355	77 000	129 000	199 000	293 000
1½	61	167	4 560	65 000	108 000	167 000	240 000
1⅜	61	153	3 835	57 000	95 000	147 000	219 000
1¼	37	179	3 175	46 000	77 000	118 000	174 000
1⅛	37	161	2 575	38 000	63 000	97 000	145 000
1	37	143	2 035	31 000	51 000	79 000	117 000
⅞	19	175	1 565	23 000	38 000	58 000	87 000
¾	19	150	1 150	17 000	28 000	44 000	66 000
⅝	19	125	800	12 000	20 000	32 000	47 000
½	7	167	525	7 800	13 000	20 000	29 000
7/16	7	147	400	6 000	10 000	15 000	23 000
⅜	7	125	295	4 400	7 400	12 000	18 000
5/16	7	104	205	3 100	5 200	8 300	13 000
9/32	7	94	165	2 600	4 300	6 800	10 000
¼	7	83	130	2 100	3 500	5 400	8 300
3/16	7	63	75	1 200	2 000	3 100	4 800
⅛	7	42	33	540	900	1 400	2 200

a = Ordinary.
b = Siemens-Martin.
c = High Strength.
d = Extra High Strength.

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River Crossing Wire.

There are certain conditions both in power work and in telegraph and telephone work where strength is very much more important than conductivity. When a telegraph line crosses a river, it is sometimes necessary to use material that will admit of very long spans or to resort to a submarine cable. When a power line comes to such a place, it is not only necessary to provide a submarine cable but transformers at each side. A power line is likely to carry 100,000 volts, and submarine cables are not built for such high voltages. It is, therefore, highly desirable in a power line to transmit current over a long span of some kind of material. Copper is not strong enough to stand a very long span, so river-crossing wire may be used where the amount of current is small; galvanized strands where the amount of current is larger. The galvanized wire or strand may be used as a conductor when the current is not large, or it may be used to carry a copper conductor when a large amount of current must be carried. In some cases a combination strand consisting of one or more copper wires with the rest of the strand made of high strength steel wires has been used, but this construction is not recommended.

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DOUBLE GALVANIZED PLOW STEEL RIVER CROSSING WIRE.

No. B.W.G.	Diameter in mils.	Pounds per		Breaking strain in pounds.	Ohms per	
		1000 feet.	Mile.		1000 feet.	Mile.
4	238	153.6	811	8400	1.86	9.86
6	203	111.7	590	6470	2.56	13.56
8	165	73.9	390	4000	3.88	20.51
9	148	59.5	314	3540	4.82	25.47
10	134	48.9	258	3000	5.87	31.01
11	120	39.0	206	2480	7.36	38.84
12	109	32.2	170	2140	8.91	47.06

Temperature is 68° F.

Unless otherwise specified wire is usually furnished in catch weight coils 22″ inside diameter, weighing from 50 to 175 pounds each. Special length coils can be furnished as heavy as 350 pounds each. All coils of river crossing wire are free from splices of any description. The galvanizing on this wire is extra heavy so as to secure the maximum amount of protection against corrosion. The average mile ohm equals 8000.

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TROLLEY WIRE.

Trolley wire may be hard copper, bronze, steel wire, either bright or galvanized. It may be round, or of special shape, so as to allow the suspending ears to be attached to the upper lobe of the wire, leaving an uninterrupted surface for the trolley wheel. The following tables give the properties and dimensions of hard drawn copper trolley wire.

STYLE 1

STYLE 2

ROUND SECTION, STYLE 1.

Number, B. & S.	Diameter mils.	Pounds per		Ohms per		Breaking strength, pounds.
		1000 feet.	Mile.	1000 feet.	Mile.	
0000	460	641	3382	.0504	.2663	8 143
000	410	508	2682	.0636	.3359	6 722
00	365	403	2127	.0802	.4235	5 519
0	325	320	1687	.1011	.5340	4 517

AMERICAN STANDARD GROOVED SECTION, STYLE 2.

Number, B. & S.	Depth, mils.	Thickness in mils of			Breaking weight, pounds.
		Upper lobe.	Lower lobe.	Web.	
0000	482	376	482	250	7 736
000	430	340	429	220	6 386
00	392	318	388	200	5 243
0	360	246	352	138	4 291

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STANDARD FIGURE EIGHT SECTION, STYLE 3.

Number, B. & S.	Depth, mils.	Thickness in mils of			Breaking weight, pounds.
		Upper lobe.	Lower lobe.	Web.	
0000	600	250	450	150	7 736
000	540	222	400	130	6 386
00	480	196	352	108	5 243
0	420	175	312	106	4 291

The weights and resistances of Styles No. 2 and No. 3 are the same as round wire Style No. 1.

STYLE 3

SPECIAL SECTIONS, NOT STANDARD.

Style.	Depth, mils.	Thickness in mils of			1000 feet.		Breaking weight, pounds.
		Upper lobe.	Lower lobe.	Web.	Pounds.	Ohms.	
4	746	314	560	190	1003	.0322	12 100
5	420	344	625	235	641	.0504	7 736
5	350	243	516	123	404	.0800	5 243
6	875	309	456	194	1088	.0297	12 900
7	640	395	395	160	641	.0504	7 736
7	485	288	288	100	404	.0800	5 243
8	980	307	357	175	1094	.0295	13 000
9	750	357	563	250	1262	.0256	14 500

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STYLE 4

STYLE 5

STYLE 6

STYLE 7

STYLE 8

STYLE 9

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STEEL TROLLEY WIRE.

There are certain places where a hard drawn copper trolley wire gives unsatisfactory service, and for such places a trolley wire made of steel is more permanent. Steel trolley wire is furnished either bright or double galvanized, in the ordinary Round Section or in the American Standard Grooved Section, the dimensions of which havo already been given under the head of Copper Trolley Wire. The weights and resistances of the American Standard Grooved Section are the same as for round steel wire, and the breaking strain is about 90% of that of round wire. The standard reel is 48″ in diameter by 22″ wide, and holds 2500 pounds in one length, although any amount up to 10,000 pounds can be furnished on a special reel in a continuous length.

STEEL TROLLEY WIRE.

Size, B. & S.	Pounds per		Ohms per		Breaking weight.	
	1000 feet.	Mile.	1000 feet.	Mile.	Bright.	Galvanized.
0000	562	2966	.3574	1.888	10 500	9 500
000	446	2357	.4500	2.376	8 500	7 900
00	354	1870	.5678	2.998	7 500	6 000
0	281	1481	.7161	3.781	6 000	4 800

Elongation in ten inches, depending on size.

4% to 2% for bright.

12% to 9½% for galvanized.

Elastic limit.

70% of the breaking strain for bright.

60% of the breaking strain for galvanized.

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INSULATED WIRES.

This book is not a catalogue, but a collection of tables for the user of Electrical Wires. Other books of the same size and general appearance as this describe the various insulated wires we make. The following is a list and brief description of such wires:

Weatherproof Copper Wire.

This is insulated with two or three braids, saturated with a weatherproof compound. We carry in stock the following solid wires with D B or T B insulation:

0000 and 000.....2500 pounds on reels.
00 to 3..... 550 pounds on reels.
4 to 10..... 150 pounds in coils.
12 to 18..... 25 pounds in coils.

We also carry 10, 12, and 14 B. & S. hard drawn copper, T B in stock, in coils from 150 pounds to 250 pounds.

In stranded wires we carry only triple braid on reels as follows:

1,000,000 C M	880 feet.	0000 B. & S.	3500 feet.
750,000 C M	1200 feet.	000 B. & S.	3500 feet.
500,000 C M	1760 feet.	00 B. & S.	2640 feet.
400,000 C M	1760 feet.	0 B. & S.	2640 feet.
350,000 C M	2000 feet.	1 B. & S.	1760 feet.
300,000 C M	2640 feet.	2 B. & S.	2640 feet.
250,000 C M	3000 feet.	4 B. & S.	2640 feet.
		6 B. & S.	2000 feet.

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Weatherproof Iron Wire.

We carry in stock Nos. 10, 12 and 14 B. W. G., in approximately half-mile coils. The iron is B. B. stock, with a mile ohm of about 5500 pounds.

We can also supply this in E. B. B. quality, with a mile ohm of about 4800 pounds, but we do not carry it in stock.

Slow Burning Insulation.

The wire is insulated with three braids saturated with a white fireproof paint. We can furnish this wire in drab or black, as well as white; white only is carried in stock as follows:

0000 to 3.....700 pounds on reels.
4 to 6.....350 pounds on reels.
8..... 50 pounds in coils.
10..... 35 pounds in coils.
13 to 18..... 25 pounds in coils.

Fire and Weatherproof Insulation.

This insulation consists of three braids, the inner two of which are saturated with fireproof paint, and the outer one with black weatherproof compound. We carry in stock:

8 to 14 solid, same sized coils as slow burning wire

All these wires belong to the same general class. We use the following abbreviations:

T B = Triple Braid Weatherproof.
D B = Double Braid Weatherproof.
S B = Slow Burning Weatherproof.
F & W = Fire and Weatherproof.
The Brown & Sharp Gauge is understood for Copper Wire, and the Birmingham Wire Gauge for Iron Wire.
4 T B = 4 B. & S. soft copper wire with triple braid weatherproof insulation.

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10 T B Iron = 10 B. W. G. Galvanized Iron Wire with triple braid weatherproof insulation.

12 T B H D = 12 B. & S. Copper Wire, hard drawn, with triple braid weatherproof insulation.

500,000 T B = A strand of 37 wires, each 116.2 mils in diameter, insulated with triple braid weatherproof.

Magnet Wire.

Magnet wire may be round, square, or flat. It may be stranded, or the strand may be pressed into a square or flat form. The insulation may be:

S C C = Single Cotton Covered.
D C C = Double Cotton Covered.
T C C = Triple Cotton Covered.
Asb = An asbestos tape with a wrap of cotton outside.
S S C = Single Silk Covered.
D S C = Double Silk Covered.
En = Enameled Magnet Wire.

We carry in stock the following round wire S C C or D C C:

0 to 14 = 200 pounds on reels.
15 to 20 = 50 pounds on reels.
21 to 26 = 8 pounds on spools.
27 to 32 = 2 to 3 pounds on spools.
33 to 40 = ½ to 2 pounds on spools.

Silk Magnet Wire is shipped in about the same sized package as cotton.

Flat Magnet Wire is made only to order. The number of possible combinations are infinite. Where the width is twice the thickness or more, no die is necessary. Where the width is less than twice the thickness the wire should be drawn through a die. We have many dies, but when we have to make a die a charge of $15.00 is made.

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We always notify a customer before going ahead with an order where a die must be made, giving the customer a list of the nearest dies in stock. Sometimes the size may be changed so as to take a made-up die.

Rubber Covered Wires.

There are a great many divisions of rubber covered wires, as Code Wires, Signal Wires, Automobile Wires and Cords, and Telephone Wires.

Code Wires are wires made according to the Underwriters' specifications, and they bear the Underwriters' stamps. Code wires are divided into several classes, depending on the working voltage:

R = Code Rubber Covered Wires for 600 volts working pressure or less.
R 15 = Ditto for 1500 volts.
R 25 = Ditto for 2500 volts.
R 35 = Ditto for 3500 volts.
R 50 = Ditto for 5000 volts.
R 70 = Ditto for 7000 volts.

We carry in stock only the first class for a working pressure of 600 volts or less.

14 R = No. 14 B. & S., Rubber Covered Wire, made, tested, and stamped in accordance with the Underwriters' Rules.

14 R Strand = Same as above, except conductor is stranded instead of solid.

8 and smaller are finished with a single braid.
6 and larger are finished with a tape and braid.
0 and smaller are solid, stranded, flexible or extra flexible.
00 and larger are stranded or flexible.

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Telephone Cables.

Soft copper wires are insulated with two or more wraps of dry paper, and then twisted in pairs. The paper on one wire is drab, and on the other red. The pairs are laid up in reversed layers and covered with a wrap of paper. After being dried out the cable is lead encased.

Nos. 12, 13, 14, 15, 16, 18, 19, 20, and 22 B. & S. are used.

The capacity of a telephone cable determines its size. The lower the capacity the larger the cable. These capacities are in common use—.08, .10, and .12 microfarads per mile. Capacity tests are made by testing one wire against all the rest grounded to the sheath, or by testing one wire against its mate; the other wires being grounded to the sheath. The relative values are as follows:

Usual.	Mutual.
.08	.054
.10	.066
.12	.080

Cables may have the following number of pairs: 25, 50, 75, 100, 125, 150, 175, 200, 225, 250, 275, 300.

They are sometimes laid up as follows: 30, 60, 90, 120, 150, 180, 210, 240, 270, 300.

Below twenty-five pair we have 15, 10, and 5 pairs.

The maximum number of pairs depends on the size wire and the capacity. A cable of 600 pairs of 22–.12 can be made having an outside diameter of about $2\frac{3}{4}''$.

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For the best underground work in cities, No. 19–.08 is the standard. No. 22–.12 is the smallest and cheapest cable made, and is used for short runs both underground and overhead. The larger sizes are for trunk lines and long distance service.

Lead.

The thickness of lead should depend on the size of the cable. Twenty-five pair No. 19–.08 should have a thicker pipe than No. 22–.12. It is possible to make the lead too heavy on a small cable.

Telegraph Cables.

These cables are made of Nos. 14, 16, or 18 B. & S. plain copper wires, insulated with paper or cotton, and saturated with compound before leading. They can be made in any number of conductors, but these lay up best in the order of the series given herewith:

First series—7, 19, 37, 61, 91, 127, 169, 217, 271.
Second series—3, 12, 27, 48, 75, 108, 147, 192, 243.
Third series—4, 14, 30, 52, 80, 114, 154, 200, 252.
Fourth series—5, 16, 33, 56, 85, 120, 161, 208, 261.

The thickness of insulation is usually designated by giving the outside diameter over the insulation. The following are ordinary values:

No. 14 B. & S., insulated to 5/32″.
No. 16 B. & S., insulated to 9/64″.
No. 18 B. & S., insulated to 4/32″.

The insulation may be rubber instead of paper or fibre.

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Power Cables.

The cables included under this heading are those intended for transmission of power. These are cables used by the street railway companies from the power house to the trolley wire transmitting direct current at 600 volts. These are the cables used in transmitting three-phase currents, at 6,600 volts or 13,200 volts, from the power house to sub-stations, where a transformation to a lower voltage takes place. These are the cables used in industrial plants to connect the power house with the motors running machinery. The power that they transmit may be used for running motors or for producing light.

Insulations.

There are three kinds of insulations in use at the present time—saturated paper, varnished cambric, and rubber compound.

Saturated Paper.

The copper conductors are wrapped with paper tape which is then dried and saturated. For large power transmissions in cities by electric light companies and street railway companies, there is probably no better insulation than saturated paper. For short lengths of cable paper is not as suitable as either of the other insulations, principally because it takes men with special training to install paper cables satisfactorily, and it does not pay to get a special man for a small job.

Varnished Cambric Insulation.

This insulation consists of tapes of cotton cloth, specially treated, and covered with a baked-on film

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of varnish. The varnished cloth tape is wound on the cable and a sealing compound is introduced between the layers. This insulation occupies a place midway between paper and rubber. It is more waterproof than paper but less so than rubber. Paper cables must have a lead cover if they are used underground, and cambric cables should have a lead cover. A paper cable without a lead cover will last two or three months even if submerged in water, a cambric cable longer; but eventually both the cambric and the paper will become saturated with moisture.

Rubber Insulation.

Rubber insulation consists of compounds of rubber and various other materials. There is practically only one kind of paper insulation or cambric insulation, but there may be an infinite number of rubber compounds varying in the amount of rubber used, and in their electrical and physical qualities. For some purposes a cheap rubber compound is as satisfactory as a higher-priced one.

There are several types of cables used for various purposes which may be described as single conductor, two conductor, three conductor, and four conductor cables.

Single Conductor Cables.

These cables are used for the transmission of direct currents and may be insulated with any of the three kinds of insulation. For paper or cambric the size should not be less than No. 6 B. & S., but for rubber insulated cables No. 14 B. & S. may be used. 2,000,000 C. M. is as large a cable as should be made or used.

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Two Conductor Flat Cables.

There are three varieties of two conductor cables, which we may call two conductor flat, two conductor round, and two conductor concentric. The two conductor flat cable consists of two single conductor cables laid side by side and covered with the same lead pipe. The present standard name for these cables is a twin cable, but they have been called duplex cables by a great many. In order to get away from disputed terms we will call these cables "Two Conductor Flat."

Two Conductor Round Cables.

These cables consist of two conductors each consisting of an insulated conductor twisted together with jute fillers and then covered with a belt and finally with a lead pipe. These cables have been called twin cables and duplex cables. The official term to-day is duplex. In order to get away from disputed terms we will call them "Two Conductor Round" cables.

Concentric Cables.

These cables consist of a central conductor surrounded by insulation, and over that one layer of wires so designed that it covers the insulation and equals in size the inner conductor. Over these wires is a layer of insulation, and outside of all a lead pipe. The objection to this form of cable is the fact that the heat generated in the inner conductor has not a very good chance to escape. The carrying capacity of these cables is smaller for the same conditions than any other type of cables.

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They are used principally in 1,000,000 C M for electric lighting where duct space is exceedingly valuable.

Three Conductor Cables.

These cables are used for three-phase currents and consist of three conductors twisted together with jute fillers and covered with a belt of insulation, and outside of that a lead pipe.

Four Conductor Cables.

These cables are not very extensively used, they consist of four conductors laid up around a jute centre, covered with a belt, and outside of all a lead pipe.

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